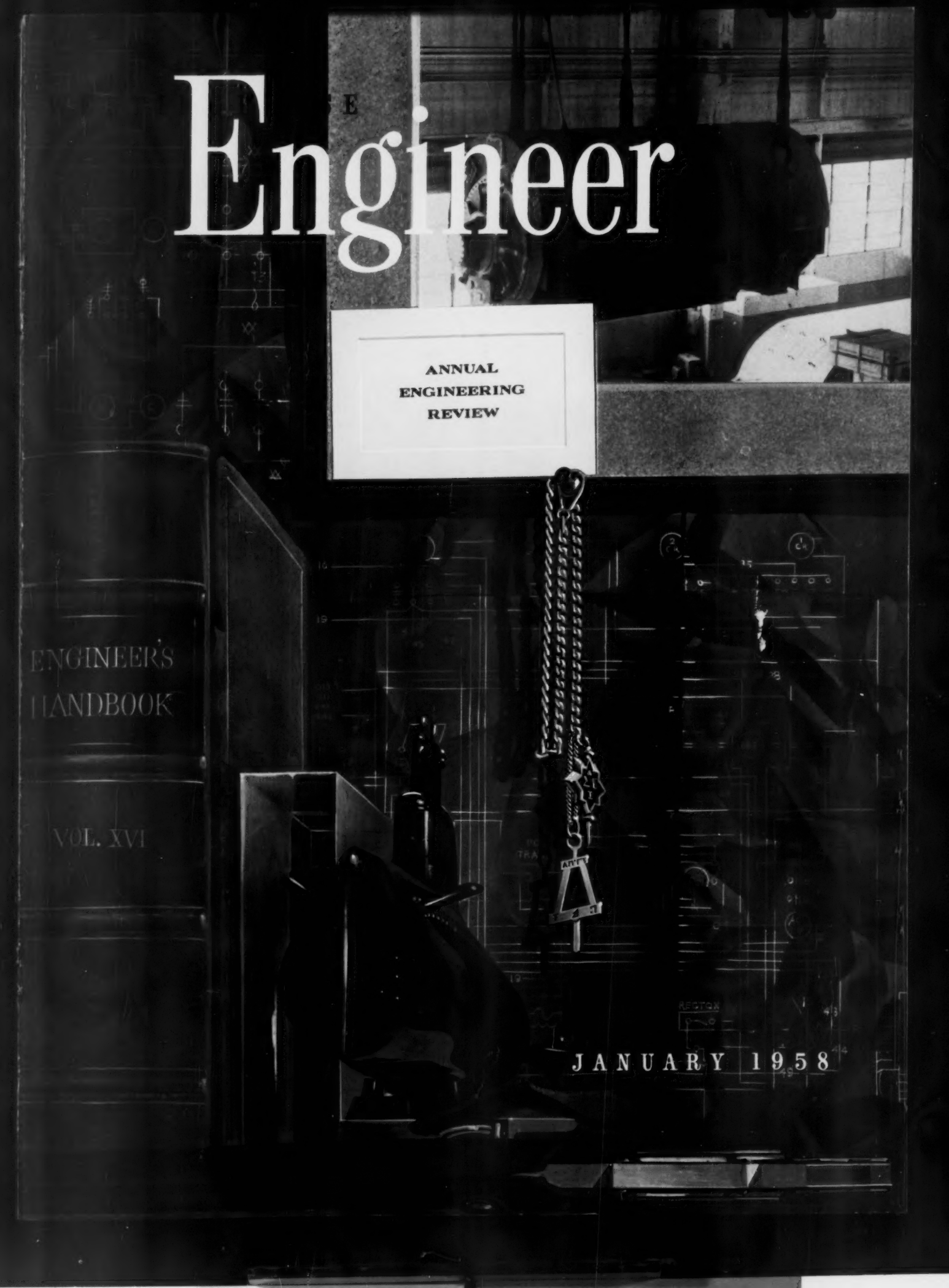
Engineer

ANNUAL
ENGINEERING
REVIEW



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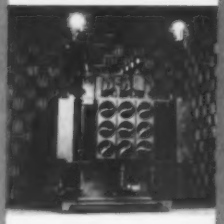

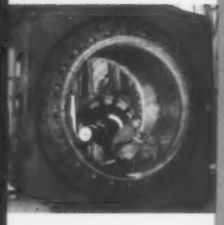

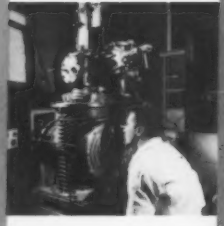

About a month before this issue was published, on December 1, 1957, the bust of George Westinghouse was placed in the Hall of Fame in New York City. Both during his lifetime and since, Westinghouse has been praised for his abilities as an inventor, as an engineer, as an industrialist, as an employer—and as a man. He was called "in character and in achievement one of the great men of our time" by Lord Kelvin; and "every inch a man and a gentleman" by a veteran Westinghouse employe.

But he was more than these. Not only was he an inventive genius himself, but he was extremely adept at spotting the same characteristics in others, and in bringing forth their best efforts. His enthusiasm and his convictions were contagious.

The record of George Westinghouse's achievements is available for all to see. But this year's review of engineering developments by the company George Westinghouse founded offers a singular means of evaluating his contributions to the world. Consider, if you will, as you read this issue, that many of these developments of 1957 might not even exist but for his persistent and successful advocacy of a-c power.

George Westinghouse was a prolific inventor. Starting with his first one at age 19, he was awarded 361 patents during his lifetime, or an average of one every six weeks during his working life. In his most productive years, he was awarded 134 patents during a ten-year period from 1880 to 1890.

Westinghouse was a rare combination of the man of action and the dreamer. Even as he invented devices for use in his day, he was thinking of the future. In a conversation with Lord Kelvin, he spoke of radium and its strange characteristics—and prophesied a new source of power yet to be found. That new source of power is now reality, as is indicated by a section of this issue devoted to power from the atom.

The true value of a man's achievements often is not apparent during his lifetime—although George Westinghouse achieved a fair measure of acclaim during his. The best evaluation can be made only after the passage of time has lent perspective. The time has passed—and Westinghouse's entry into the Hall of Fame is ample evidence of his contributions.

COVER DESIGN: In this issue, we talk about engineering accomplishments. Cover artist Dick Marsh appropriately pays tribute to the engineer by choosing objects associated with the engineering profession as the subject for a still life.

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ANNUAL ENGINEERING REVIEW

of the year 1957

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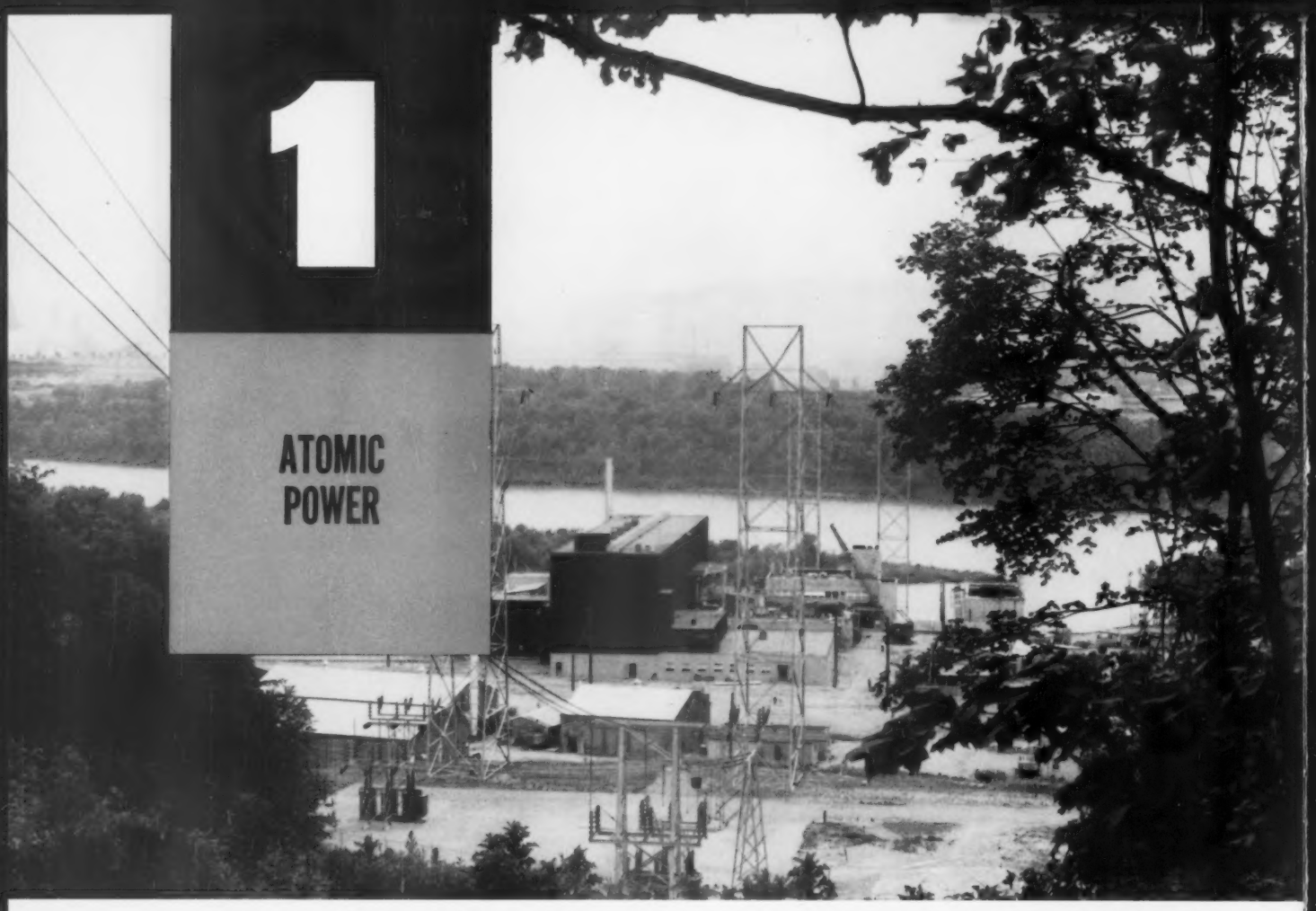
ATOMIC POWER



The Pressurized-Water Reactor at Shippingport, Pa., the first large-scale nuclear power plant in the United States for the generation of electricity, was completed in 1957. The initial capacity of the plant is in excess of 60 000 kilowatts.

This pioneering atomic power station was built as a joint venture by the Atomic Energy Commission and the Duquesne Light Company of Pittsburgh. Westinghouse developed the nuclear components under a contract with the AEC. Duquesne Light Company built the electric generating portion of the plant and is operating the entire station.

ELECTRIC UTILITY

atoms on the move

■ *Yankee*—The Yankee Atomic Electric Company's planned nuclear-power plant approaches reality; land has been cleared for the new station near Rowe, Massachusetts, and active construction will be initiated in early 1958. This is the electric company formed by 12 of the major power companies in New England. The plant is being built under the provisions of the Atomic Energy Commission's Large Power Reactor Demonstration Program.

Planned to produce 134 mw of electricity, the Yankee plant will have a Westinghouse pressurized-water reactor system with some major modifications from the Shippingport design. Completion date for the plant is December 1960.

All of the long-term component parts, such as the canned motor-pumps and steam generators, are on order. The reactor core is in the final design stages. Engineers of the Yankee Project conducted a "criticality" experiment on the core in October. The experiment is a means of checking design calculations on the necessary number of fuel elements and control rods and their geometrical arrangement. The actual Yankee core calls for some 23 000 fuel elements and 24 control rods. The "criticality" experiment was scaled down to approximately 5800 fuel elements and 9 control rods.

Edisonvolta—An atomic-power plant for Italy seems assured with the announcement early in 1957 that the Edisonvolta S.p.A. plans to purchase essentially a duplicate of the Yankee pressurized-water reactor from Westinghouse. The companies of the Edisonvolta group, headed by Soc. Edisonvolta, have the largest electric system in Italy, producing around 9 billion kwhr per year. With the limitations in hydroelectric development and necessary importation of all conventional fuels, the Italian utility group expects that much of their future electrical load must come from atomic power.

Pennsylvania Advanced Reactor—The original agreement two years ago between the Pennsylvania Power and Light Company and Westinghouse for the development of an aqueous homogeneous reactor, was divided into several phases. Phase I could be summed up in one word—feasibility. In effect: was it possible, both technically and economically, for such a reactor to be ultimately competitive with a conven-

tional power plant? Phase II consists of the detailed development investigations necessary for the final engineering design.

Phase I is still in progress but emphasis is now changing to concentrated effort on the few remaining major feasibility problems. One of the earliest obstacles that seemed almost insurmountable was the expected corrosion-erosion of the primary loop by the circulation of a slurry of thorium and uranium oxides. Tests on experimental loops showed that with stainless steel and proper chemical control, erosion rates are not constant but level off. In fact, they barely exceed the rate for water on carbon steel—about 1 to 2 mils per year. After continued pumping of the slurry, the particles in suspension lose their jagged edges and become rounded.

Since the radioactive material is not contained in solid fuel elements, such as in a pressurized-water reactor, but circulated continually, most of the other problems are also concerned with the loop. Thus, test loops have become almost the byword of the PAR (Pennsylvania Advanced Reactor) project. To date, some 11 of them have been built.

Two were used to check "pumpability" of various proportions of solid and liquid. Four 200-gpm loops have been used for corrosion-erosion studies. (Two of these have been running for over a year.) Other loops are made of glass to study slurry distribution and control. The largest of all is loop D—which will circulate slurry at one half the rate of one of the loops in the final plant design. Here slurries can be circulated from atmospheric pressure to 2000 psi. It will be used primarily for component development and systems work and to verify maintenance procedures. Jigs and fixtures are being developed for remotely taking out pumps, tearing them apart, replacing bearings, and putting them back together again, etc.

Belgian Thermal Reactor—In late 1957, the Belgian nuclear energy society, the Syndicat d'Etude de l'Energie Nucleaire, broke ground for their atomic power plant near Mol, Belgium, about 40 miles northeast of Brussels. On this side of the Atlantic, Westinghouse moved ahead in the manufacture of the nuclear reactor, canned motor-coolant pumps, steam turbine and steam generator for the Belgian plant, now called the BR-3. The reactor will be of the pressurized-water type and the electrical output of the plant itself will be 11.5 mw. The Belgian government has already built two nuclear test reactors, designated BR-1 and BR-2, for radiation studies of materials. The manufacturing timetable set up for Westinghouse components for the BR-3 calls for completion of the turbine, pumps, and steam generator in November 1958. The reactor core is scheduled for completion in March 1959. Equipment is to be shipped as it is completed and the Belgian nuclear group is looking to late 1959 operation of the plant.

Belgian and Italian Licenses—Additional atomic power plants for Belgium seem assured with the signing of a technical assistance agreement in 1957 between Westinghouse and Belgium's largest electrical manufacturing company, Ateliers de Constructions Electriques de Charleroi. The agreement opens the way for the A.C.E.C. to manufacture nuclear reactors of the pressurized-water type. A similar manufacturing-technical assistance licensing arrangement was set up between Westinghouse and Fiat, S.p.A., one of Italy's leading manufacturers. Both Fiat and the Belgian firm will have access to design information for land, marine, and aviation use, including fuel elements, reactor cores, and the auxiliary apparatus. Westinghouse will train engineering and operating personnel.

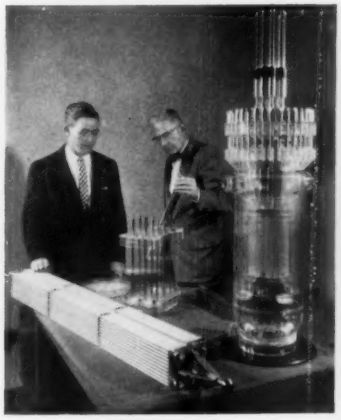
Carolinas-Virginia Group—Another atomic power plant study was initiated in mid-1957 between Westinghouse and the Carolinas-Virginia Nuclear Power Associates, Inc., a group of four southern utility companies. The initial study work has been completed, and the present effort directed toward planning the program to be pursued in the development of a prototype plant of advanced design permitting eventual installations of very large nuclear power plants. ■

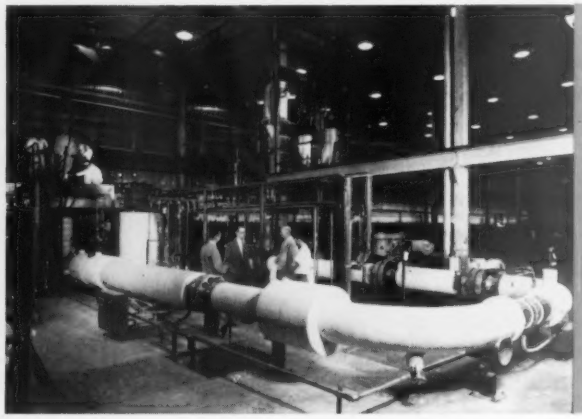
vertical steam generator

■ In the atomic-power plant, the steam generator is the transition point between the new—the nuclear heat source—and the conventional, the steam turbine. In the steam generator, the heat from the hot water circulating through the nuclear reactor core is used to generate steam, which drives a steam turbine. At this point, then, something other than a conventional steam generator design might be expected—and indeed it is.

A vertical steam-generator unit developed is particularly suitable for installations where space and weight are at a premium. Also, extreme simplicity minimizes the problem of preventing any possible leaks from the high-pressure nuclear system coolant.

Here is how the new vertical steam generator works. Hot gas from the combustion of conventional fuel is replaced by hot water from the nuclear reactor, which circulates through inverted "U" tubes, and back to the reactor. The U-tube design eliminates many of the expansion problems of other types of steam generators. Whereas a conventional steam generator has considerable outside piping, such as downcomer pipes to carry water from the steam drum back down to the boiler for re-evaporation, this unit has no outside piping. The downcomer pipes, for example, are replaced by an annular





Left—Models, both full size and scaled-down, play an important part in nuclear reactor design. Shown (left to right) is a rod-type fuel assembly and models of a core support plate, an array of various types of fuel rods, an experimental fuel tube array, and a small power reactor. Only the rod-type fuel assembly is full scale.

Right—D-loop for homogeneous reactor tests.

passage built inside the boiler shell. This arrangement eliminates the external piping normally required for risers as well as downcomers, and greatly reduces the required floor area, which is of the utmost importance for marine applications.

Three stages of moisture separation are employed at the top of the boiler to keep steam moisture to a minimum, even during transient conditions that might be called for by rapid changes in power requirements.

The vertical steam generator design is being adpated to the larger sizes needed for commercial services. Present applications under consideration are the Yankee Power plant and the homogeneous reactor plant being studied in a joint development program between the Pennsylvania Power and Light Company and Westinghouse. ■

testing atoms

■ *WTR*—Construction of the Westinghouse Testing Reactor is underway. The first test reactor to be privately financed, it will have complete facilities for studying radiation effects on materials—structural metals, fuel elements, fluids, inorganic and organic samples. It is scheduled for completion in early 1959. The power output of the reactor is 20 mw with designed-in capabilities of 60 mw. Heat—so eagerly withdrawn and jealously guarded in power plant reactors—is a waste commodity in the WTR. Heat exchangers and cooling towers release reactor heat to the atmosphere. Around and within the reactor core itself are 129 "thimbles," or test holes, in which various sized material samples can be inserted. The thimbles range from 6.5-inch diameter, 48-inch length to ½-inch diameter, 40-inch length. There are holes in which test specimens can be inserted; then quickly withdrawn. In other holes, specimens can be placed with a maze of attached instrumentation cables and sampling cables.

The test reactor has certain other valuable functions. One of these is the production of radioactive isotopes. Most well known is cobalt-60, with its important diagnostic and treatment functions in the medical profession.

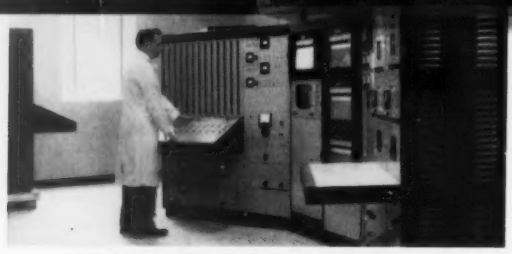
WREC—On the same 850-acre tract as the WTR, 30 miles southeast of Pittsburgh, is the Westinghouse Reactor Evaluation Center. This building is complete and has already been used to check reactor calculation on a prototype core of the proposed Yankee reactor. Three main sections make up the evaluation center—a combined office and shop area, a control room, and a high bay critical experiment room. Within the critical experiment room is a 37-foot steel girder tower, which will support a nuclear core tank as tests are conducted. Tests are conducted by remote control from the control room and readings taken on a console monitoring set. Closed-circuit television will permit the operators to observe activity. ■

SHIP PROPULSION

the nuclear fleet grows

■ Since launching in early 1955, the first atomic submarine, the U.S.S. *Nautilus*, continues to break all submarine records for continuous operation, speed and duration of submerged travel.

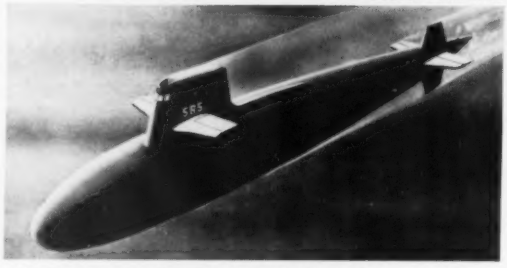
In May 1957, the *Nautilus* returned to its launching site at Groton, Connecticut for a new nuclear-fuel charge. It had traveled 62 500 nautical miles, almost two and a half times around the world, and was submerged for 36 500 miles. The Navy announced that the history-making operation of the *Nautilus* on her first nuclear-reactor core spectacularly demonstrated the military advantages of nuclear propulsion. By September 1957, the *Nautilus* had chalked up 20 000 miles on



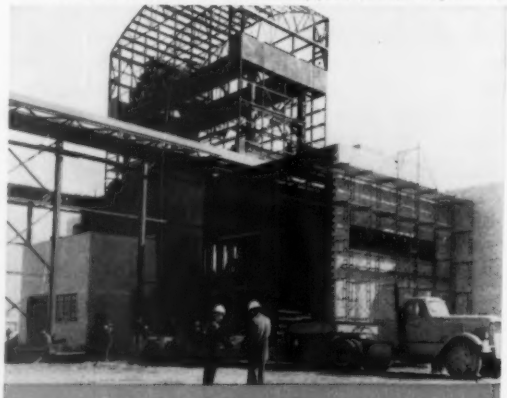
Console Room at Reactor Evaluation Center

U.S.S. *Skate*

U.S.S. *Swordfish*



Artist's conception of U.S.S. *Skipjack* (*U.S. Navy Photo*)



Construction of facilities for a nuclear propulsion plant for a large naval surface ship are shown well underway at the Naval Reactor Facility at Idaho Falls, Idaho. Being designed by Westinghouse under contract with the AEC, the prototype propulsion plant will be capable of powering one shaft of a large naval surface vessel. The reactor will be of the pressurized-water type similar to the unit which powers the U.S.S. *Nautilus*. The "keel" for this land-based ship, designated the AIW project, was laid at the Idaho site alongside the submarine prototype engine which Westinghouse designed for the AEC in 1953. The nuclear power plant will be housed in an exact replica of a portion of a ship's hull. Other buildings will house laboratories, shops and storage areas.

its second nuclear core. On a real record breaking run from New London, Connecticut to San Diego, California via the Panama Canal, the *Nautilus* surfaced only at the canal, traveling submerged 4956 miles out of 5229. It cruised at speeds between 18 and 20 knots from Panama to San Diego.

Late in 1957, the *Nautilus* was scheduled to be joined by the U.S.S. *Skate*, the third atomic submarine. Equipped with the same type of reactor plant as the *Nautilus*, a pressurized-water system, the *Skate* is shorter in length. The nuclear reactors for four other submarines of the same class as the *Skate* are being designed and developed by Westinghouse Electric Corporation at the AEC Bettis Plant in Pittsburgh, and are at various stages of completion. These reactors will power the U.S.S. *Swordfish*, U.S.S. *Sargo*, U.S.S. *Seadragon*, and the U.S.S. *Halibut*. The *Halibut* will be the first submarine constructed for the Navy as a nuclear-powered guided-missile submarine. The necessary steam generators, turbines, gears, and condensers for these five submarines are also being furnished by Westinghouse.

Another group of ten submarines are part of the Navy's announced nuclear fleet. The first ship of the group is the U.S.S. *Skipjack*, being built from the keel up for continuous underwater operation. The Navy has announced that in addition to improved maneuverability, the *Skipjack* will travel submerged at high sustained speeds. The nuclear reactor plant for the *Skipjack* is being designed and developed for the Atomic Energy Commission by Westinghouse at the Commission's Bettis Plant.

Progress is also being made on nuclear-powered surface ships. The nuclear reactor plant for the U.S.S. *Longbeach*, a guided-missile light carrier, is being designed and developed at the AEC Bettis Plant. Construction work is also well underway at the Naval Reactor Facility in Idaho on the prototype plant for large naval surface ships. Buildings are being erected to house the atomic power plant, laboratories, and related facilities. Actual design of the nuclear portion of the unit—a pressurized-water reactor type of advanced design—is being carried out at the AEC Bettis Plant. Completion of this latter project will signal the start on the eight reactor cores for the actual sea-going carrier.

Thus the nuclear fleet grows—soon there will be perhaps a half dozen launchings per year. As each hour of operation passes—whether on or under the sea or on a "land-locked" prototype—priceless learning and experience is gained. A new Navy is in the making! ■

PLANT EQUIPMENT

equipment for atomic power plants

■ Liquid sodium and sodium-potassium alloys have high boiling points, stability at high temperature, and good heat transfer characteristics. Being slightly lighter than water and of a similar viscosity, they require about the same amount of power to pump as water. It was natural that a leak-proof canned motor-pump should be developed for pumping-liquid metals. A 15 brake-horsepower prototype model has been tested at temperatures as high as 1265 degrees F; a long cycle test was voluntarily discontinued after 3000 hours of successful operation at 1000 degrees F. Operation at these temperatures proved the pump design, and particularly the motor temperature, to be completely independent of the liquid-metal stream temperature. Thus the metal stream temperature is only limited by the availability of materials for the hydraulic pump parts. Limitation at present—1600 degrees F.

Four liquid-metal canned motor-pumps are now being manufactured: two are 170 brake horsepower and two are 700 brake horsepower.

Control-Rod Mechanisms—The various control mechanisms necessary for the accurate and safe operation of a nuclear reactor are complex. For example, a great many engineering manhours have been spent on devices to properly insert and withdraw the neutron-absorbing control rods. For submarine reactors, a screw-type mechanism was used to raise and lower the threaded top portion of the control rod with a rotating split-nut arrangement providing the power. The split-nut arrangement was vital to allow quick disengagement from the rod in the event of emergency shutdown. During normal operation, on the other hand, a positive hold between nut and rod was needed to prevent rod release in the event of external shock such as collision or perhaps depth charges. With the elimination of shock possibility in land-based reactors, a novel jack-type control rod drive mechanism has been developed. In place of the threaded-end control rod in naval reactors, the top portion of commercial reactor rods consists of a bundle of six ½-inch stainless-steel rods. Surrounding this bundle are two split rings whose inner surfaces are shaped to the contour of the six-tube bundle. The opening and closing of the split rings is controlled by magnetic coils. In operation, the lower ring closes, grips the rod bundle, and lifts a preset distance. Here, the upper coil closes and holds the rod bundle while the lower ring opens then drops for a new gripping position. In emergencies, or in case of power failure, both rings are released allowing the control rods to drop.

The new jacking mechanism provides extremely accurate positioning, and travel rate can be varied, (1) under controlled travel rate from zero to approximately eight feet per minute, and (2) under scramming acceleration rate approximating one g. No latching parts are required and close tolerance pieces are at a minimum. First application will be on the Belgian reactor BR-3.

Steam Generators—Four giant steam generators being built for the Yankee reactor project are the largest of their kind. The Yankee system will have four separate main cooling loops, each with its own steam generator and canned motor-pump. The steam generators are vertical units rather than the usual horizontal type and each is 38 feet high and 7 feet in diameter. Empty weight is 83 tons—filled, 114 tons. Water enters the bottom of the generator at 2000 psi and 530 degrees F, and then passes through 1620 U-tubes made of ¾-inch stainless steel. The tube support plate is 7 feet in diameter and 13 inches thick, clad on the pressurized loop water side with ½-inch thick stainless steel. The tube bundle is surrounded by a "wrapper" of thin metal, which forms an annular passage between the wrapper and the pressure cell for incoming feedwater from the turbine condensers. The bottom of the wrapper is parted, permitting feedwater flow into the tube bundle. Boiling takes place in the tube bundle, and due to the difference in density between boiling water in the bundle and the cooler feedwater, natural circulation is established. The top of the wrapper is of reduced diameter and contains a centrifugal device which serves as the first stage of steam separation. The bulk of the water is removed at this point. The annular volume between the shell and the separators is quite large at this point, thus providing water storage. The steam drum is merely an extension of the shell and contains two more stages of moisture separators. The first stage consists of a square array of vertical chevron-type separators while the final separation is accomplished by a Centrifix purifier. Residual moisture in steam delivered to the turbine will be one quarter of one percent. ■

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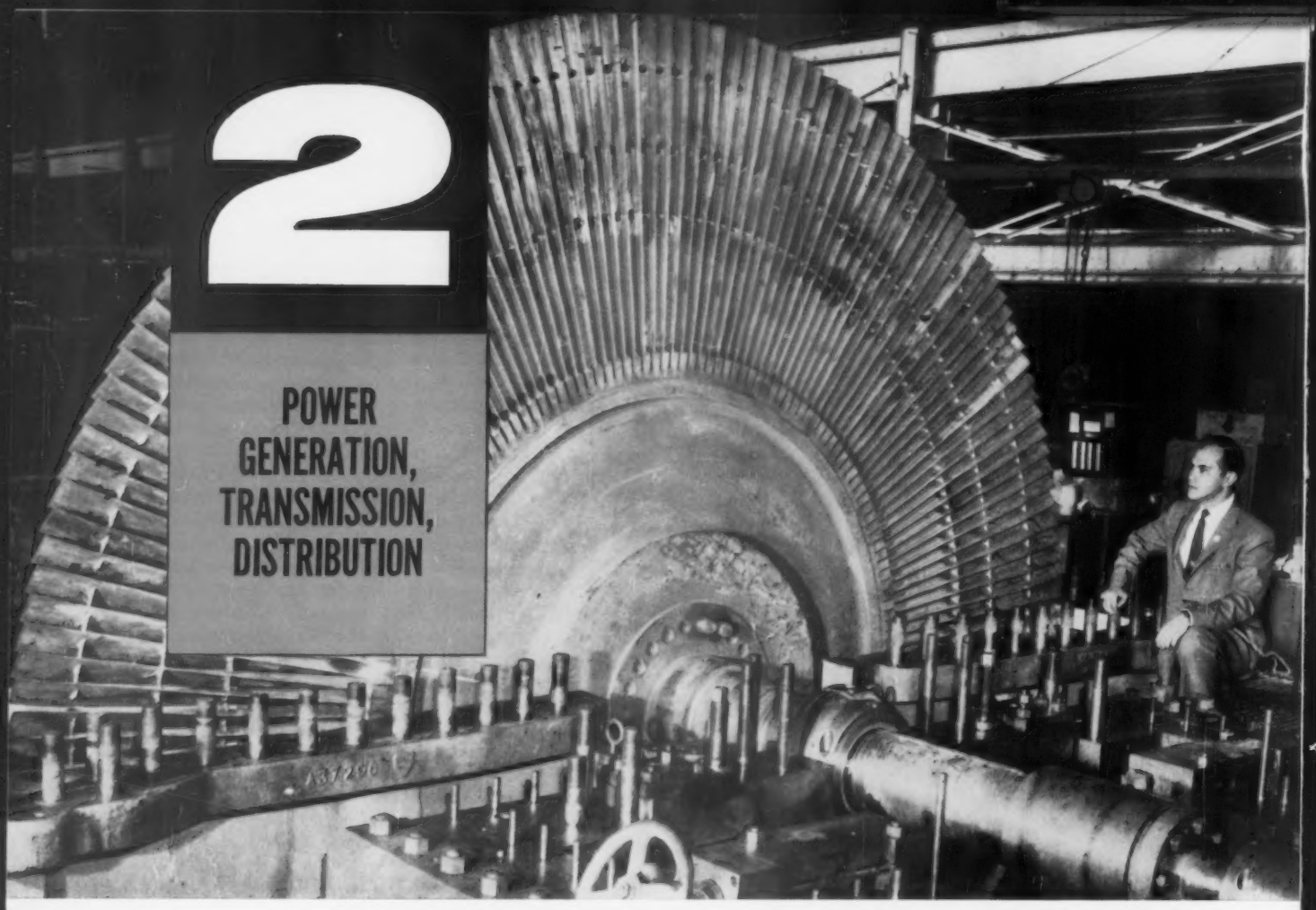
POWER GENERATION, TRANSMISSION, DISTRIBUTION



Engineers are putting key parts of the super-pressure 5000-psi steam turbine, being built for the Philadelphia Electric Company, through their paces. Test equipment is now being built for subjecting the solid Discaloy super-pressure rotor to rotational overspeed tests at operating temperature to check the forging stability. A duplicate forging of G-18-B, a European gas-turbine material, is also being readied for test.

At the other end of the machine, engineers are subjecting these giant 44-inch exhaust blades to rotating and stationary vibration tests. On the rotating test, engineers are recording all information on tape so that it can be played back for more comprehensive analysis.

TURBINES AND GENERATORS

3600/3600 is a hit

▪ The cross-compound 3600/3600-rpm turbine-generator unit, first reported on these pages last year, has proven one of the most interesting turbine designs made available to the utility industry.

In a nutshell, the unit works like this: the high-pressure turbine is coupled with a double-exhaust, low-pressure condensing element; this shaft is cross-compounded with an intermediate-pressure turbine coupled with a second duplicate double-exhaust, low-pressure condensing element. Steam enters the high-pressure turbine, then after reheat crosses to the intermediate-pressure turbine on the other shaft; the steam is exhausted at both ends of the intermediate-pressure turbine and flows through crossover pipes into the two double-exhaust, low-pressure condensing elements, one on each shaft. The most important feature of the design is the near duplication of the two parallel turbine-generator shafts. The only difference is that one has a high-pressure turbine, the other an intermediate-pressure turbine; everything else, the low-pressure elements, the generators, and the associated switchgear components are duplicated.

Including the original two units for Public Service Electric and Gas Company of New Jersey, a total of nine units is now on order. The machines will range in size from 200 to 300 megawatts, with a total capacity of about 2400 mw. All will operate at conventional pressures, from 1800 to 2400 psi, and inlet steam temperatures of 1000 to 1100 degrees F. The shafts of each cross-compound unit will use duplicate generators. ▪

5000-psia boiler feed-pump drive

▪ The steam-turbine drive for boiler feed pumps, long sitting on the bench in favor of the electric motor, is being called back into service to help provide the unusual injection pressure requirements of the 5000-pound super-critical turbine boiler. The variable pressures required, ranging from 3500 psi to 5000 psi at full load, have made the variable-speed features of the steam turbine especially desirable.

Actually, the 5000-psi turbine will utilize three boiler feed pumps, connected in series. The first two, a low-pressure and

an intermediate-pressure pump, will be driven by electric motors. The third high-pressure pump, driven by the steam turbine, will take water at 4200 psi and deliver it to the boiler at pressures up to 6250 psi.

The versatility of the steam-turbine design can be appreciated by considering the conditions under which it will operate. Steam to drive the turbine will be extracted from the main unit from the first cold reheat at approximately 1110 psia, 785 degrees F. Consequently, the steam conditions to the unit will vary depending upon generator load. Since boiler injection pressure requirements will also change with load, the pump-turbine speed control must balance this variable "supply and demand" to provide the correct feed-pump drive speed. ■

progress in inner-cooling

■ Last year, two years after the first inner-cooled generator was placed in service, we reported 13 of these machines shipped. Now, one year later, this figure has been more than doubled—a testimonial of the acceptability of the inner-cooled design.

A specific indication of the design advantages made possible with inner-cooling can be gained by taking a quick look at rotor sizes. The largest Westinghouse conventional non-inner-cooled machine (184 mva) has a 43-inch diameter rotor; a new 385-mva inner-cooled machine will have a 40-inch rotor—inner-cooling has made it possible to more than double the generator rating with a smaller diameter rotor.

However, stator sizes must get larger, to accommodate the increased ratings. Inner-cooling temporarily reduced this physical growth, but as ratings continue to jump, machine size continues to increase, to the point where shipping will again become a design problem. Transportation methods limit machine sizes, as well as overall machine weight. The first inner-cooled machine could be shipped in one piece; however, weight restrictions made it necessary to remove the rotors of the largest inner-cooled units now in service; and engineers are designing future machines that will be within shipping space limitations. ■

generators for Niagara

■ An order for thirteen 167 000-kva waterwheel generators for the $600 million Niagara power project has been awarded Westinghouse by the New York State Power Authority. The units represent the largest single order of its kind ever placed in the United States.

Preliminary estimates indicate that shipment of the parts for only one of the generators to the Niagara site will require 34 railroad cars. The first unit is scheduled for delivery by September 1, 1959.

With a maximum dependable capacity of 1 800 000 kilowatts, the Niagara project when completed will become the largest hydroelectric project east of the Mississippi River and the second largest in the United States. Only Grand Coulee in Washington State has a greater capacity.

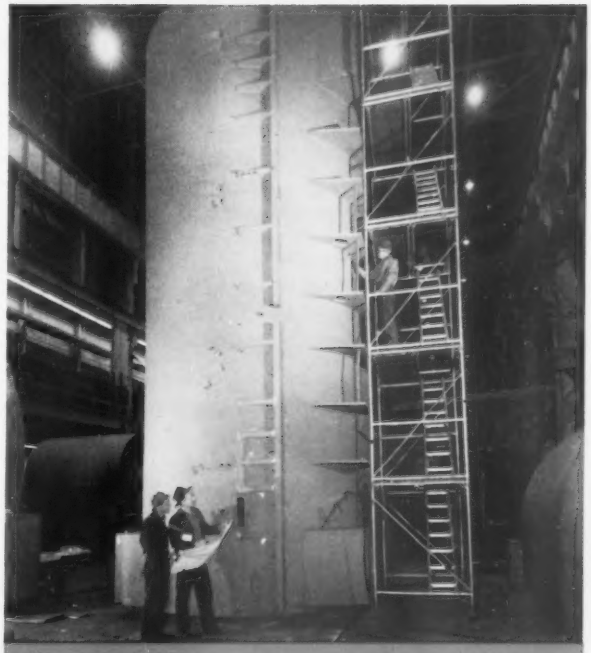
Almost the full difference between the levels of Lake Erie and Lake Ontario will be used in the production of power. Whereas the Schoellkopf plant has a head of 215 feet and the old Adams Station, a head of 135 feet, the new project will drop water 314 feet. ■

corona "foiled" on turbine-generator windings

■ Since the trend in turbine-generator design has been toward higher voltage for added power output, an improved means for suppressing corona on the diamond ends of high-voltage stator half coils was desirable. In the past, a high-resistance surface coating (Coronox) has provided corona suppression; a new method will provide improved corona suppression at voltages above 20 kv.

This method consists of imbedding a series of variable-length foils at various levels on each end of the half-coil ground-wall insulation. This eliminates corona discharges on the surface of each coil, between adjacent coil surfaces, and from coil surfaces to ground elements of the stator. It accomplishes this by reducing the voltage difference between adjacent parts of the winding. The foils are so positioned that the capacitive reactances between foils, between foils and copper, and between foil and conducting varnish distribute the voltage on the surface of the coil as well as across the ground-wall insulation. ■

Corona is eliminated by imbedding foil in winding insulation.



This is one of three 320-mva inner-cooled generators being built for the City of Memphis, Tennessee.

These units, in addition to two units of comparable rating previously built in the East Pittsburgh plant of Westinghouse, are the largest generators that have been built to date. The huge frame shown in an upright position is being inspected by workmen preparatory to turning it on its base for further assembly operations.

Most powerful generator transformer.

The "Schnabel," the nation's first three-part railroad car, is shown being readied for its maiden voyage. The load—a huge 412 000-pound autotransformer—also serves as the center portion of the car. Two identical end sections, each about 30 feet long, support the transformer. This unique arrangement permits the transformer to be lowered to within six inches of the rails so that taller units can be shipped as a single piece of equipment, reducing installation costs and delivery time. The first shipment went to the Ohio Power Company's H. A. Kammer Plant at Foster, West Virginia. This 200 000-kva, 330-kv autotransformer, completely assembled, is almost 29 feet high, 30 feet long, and 21 feet wide.

TRANSFORMERS

bigger and bigger generator transformers

▪ The world's most powerful generator transformer—also the largest ever built—is now being installed at the Detroit Edison Company's River Rouge plant. The 360-mva generator transformer will boost the output voltage of the utility's new 325 000-kw turbine generator from 17.3 to 129 kv. The transformer, with a shipping weight of 340 000 pounds, was shipped in a one-piece tank minus bushings, coolers, and oil. The installed weight is 458 000 pounds. Approximate installed dimensions are: 24 feet high (from base to bushing tips), 26 feet long, and 17 feet wide.

The "keel" for an even larger generator transformer—rated at 380 mva—has already been laid, and construction is well under way. This unit will be installed on the Commonwealth Edison Company's system, and will raise generator voltage from 17.2 to 69 kv. The transformer low-voltage winding is rated at 380 mva; it has two high-voltage windings, each rated at 210 mva. Each phase of the high voltages is separated by a steel barrier to prevent even the remote possibility of a phase-to-phase failure in these windings.

Even as the 360-mva transformer is being installed, and 380-mva unit is being built, engineers are designing a still larger one—a 400-mva generator transformer for Public Service Electric and Gas Company of New Jersey. ▪

more "elbow room" for network transformers

▪ The network transformer, located in underground vaults, has always put emphasis on small volume, ease of maintenance, and an overload ability to meet the required contingency operating conditions. A new network transformer maintains these all-important features and also introduces a new concept in tank design. Dubbed the "Space-Miser," the new line of network transformers is 20 percent smaller than previous designs. This was made possible through a complete redesign of the core-and-coil assembly.

The most significant features of the new design are a height reduction and a new tank, both of which combine to reduce the important problem of corrosion. By reducing the height 12 inches, the unit can be mounted above the vault floor away from debris and moisture. All sharp edges and corners have been eliminated with a contoured tank of divingbell design. Flat, hollow fin-type coolers replace conventional tubes, simplifying cleaning and painting. The new network transformer line consists of 300, 500, and 750 kva ratings. ▪

corrosion-proof transformer

▪ The corrosive atmosphere of a chemical plant together with salt exposure on a sea coast produce a corrosion combination that is difficult to beat for surface deterioration of transformer tank and radiators. In a recent large rectifier installation for chlorine production at the Freeport, Texas plant of the Dow Chemical Company, the need for improvement was answered by combining a rectifier transformer and regulating transformer in a single tank and arranging the complete unit for direct sea-water cooling using a copper-nickel cooling coil. The result was a savings in floor space of 70 percent, a reduction in cooling surface exposed to atmosphere of 90 percent, and a weight reduction of 35 percent. The tank (without numerous radiators usually supplied for a self-cooled unit) was then given Coastal Finish protection. ▪

SWITCHGEAR

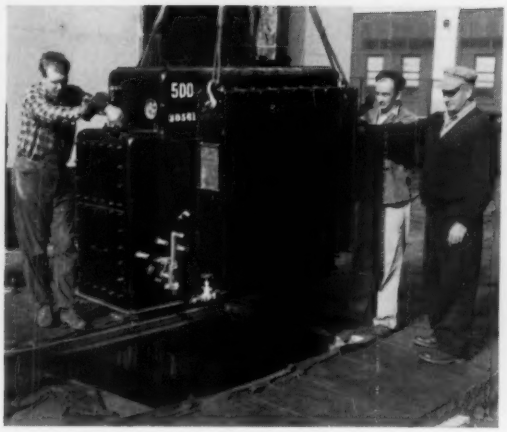
new "insides" for oil circuit breakers

▪ We normally speak of ratings being extended upwards on these pages; the tubular De-Ion grid interrupter originally designed for the 330-kv. circuit breaker, is an exception—its ratings are being extended downward. The same fundamental interrupter design has been adapted to 230, 138, and 69-kv circuit-breaker ratings.

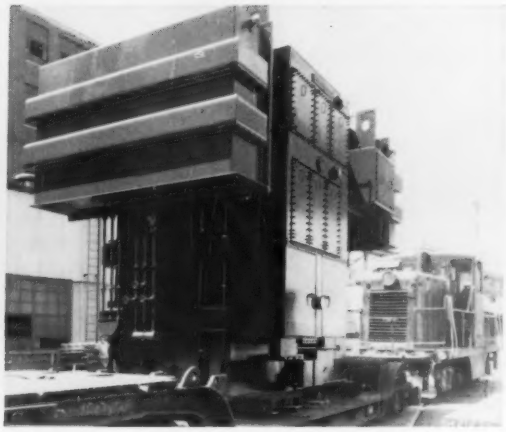
The original 330-kv interrupter consists of four identical arc-quenching units per terminal (eight per breaker phase) that operate in series. To get lower voltage ratings, it was merely necessary to use fewer "building blocks." For example, the 69-kv interrupter needs only one block per terminal.

The tubular type of construction provides for simple breaker adjustment and alignment. Parts subject to wear and erosion can be examined or removed without disturbing breaker alignment, thus permitting faster inspection and shorter maintenance periods. Identical moving and stationary contacts and interrupting elements are used on all tubular De-Ion grids 138 kv and above. This means fewer spare parts need be stocked for systems using several voltage ratings.

The tubular grid has resulted in a higher interrupting rating for the 69-kv breaker—5 million kva. The first units at this increased rating have been installed on the Florida Power and Light System. ▪



"Space-Miser" network transformer.



Corrosion-proof transformer.

maintenance made easy

▪ For obvious reasons, maintenance men do not relish working on outdoor switchgear during bad weather. This has always been a problem, solved in a variety of ways. One utility designed a portable repairhouse, which could be temporarily erected around outdoor switchgear during maintenance periods; another used a truck that could be parked beside the equipment to provide temporary shelter. Switchgear engineers have come up with a design that eliminates such compromises and is considered most practical of all. This consists of providing a permanent but relatively economical shelter, which houses the fully-assembled indoor metal-clad switchgear in a weatherproof enclosure and provides adequate floor space for maintenance of the breakers, instruments, relays, etc. The new unit assembly is appropriately dubbed Shelterfor-M.

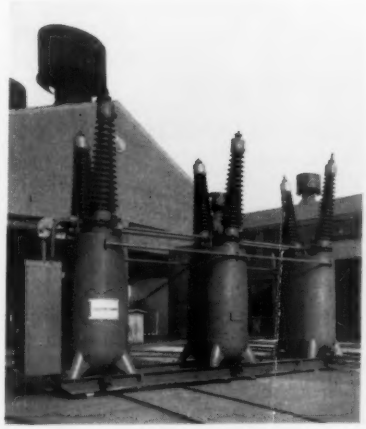
The new Shelterfor-M design has several advantages. All-weather operation and maintenance are possible. Since the new design encloses a common operating and maintenance aisle, it requires less overall plot area—as much as 40 percent—than conventional outdoor metal-clad designs. It is particularly suited to a double-row, double-bus arrangement. The common aisle provided between rows permits a weather-protected area for interchange of breakers between buses. Foundation requirements are simple and no operating or breaker drawout pad is required. Field assembly of the Shelterfor-M switchgear requires a minimum of men and manhours.

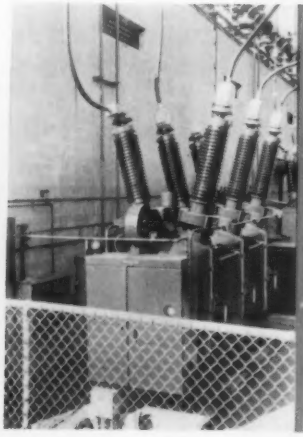
The additional "shelter" enclosure is not attached until the preassembled units are set on a prepared foundation. A metal panel covers the face of the preassembled units to protect instrument panels during shipment. During field assembly of the enclosure, this panel is removed and becomes the front wall of the enclosure. After the basic units are placed on the foundation, the front panel is moved to its proper location and interlocking floor plates are laid to provide a smooth, rigid floor surface. The floor channels of the front panel and the metal-clad compartments provide anchor points. The plates have sufficient strength to support the heaviest breaker and manpower load.

After the floor is completed, end panels are erected and the roof panels are bolted to the top of the assembly. Screened ventilating openings are provided in the enclosure. ▪

46-kv recloser

▪ Sulfur-hexafluoride gas has won for itself a place in the type designation of a new automatic switchgear device for low-capacity distribution circuits. The designation, 460SF250, when decoded, indicates that the new device is for 46-kv circuits, uses sulfur hexafluoride as the interrupting medium,

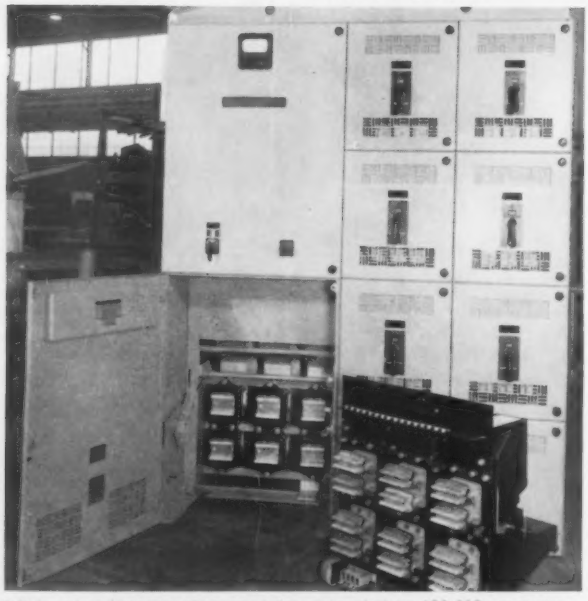




Left—This 230-kv breaker now uses the tubular De-Ion grid interrupter design, originally developed for 330-kv. breakers.

Right—This dead-tank high-capacity outdoor compressed-air circuit breaker, the first ever built, is now installed and operating on the Consolidated Edison Company of New York system. The 138-kv circuit breaker has a continuous-current rating of 1600 amperes, and an interrupting rating of 10-million kva. At this writing, a total of 15 breakers have been shipped—about one-fourth of the total number on order. Some of the breakers will be designed to be connected to 138-kv isolated phase bus. This isolated phase bus installation will be one of the first of its type in the country at this voltage.

This 46-kv recloser has a 250-mva interrupting capacity.



DB breaker interrupting capacity extended to 100 000 amperes.

Today's growing distribution systems require economical protective devices with more and more interrupting ability. The extra-high-capacity type DX open cutout fills this requirement. It offers interrupting capacities up to 10 000 amperes and 8000 amperes at 7.8 and 15 kv respectively.

Like all DX cutouts, the new high-capacity unit may be completely hook-stick operated and it is provided with deluxe tin-plated cast eye bolt terminal connectors that accept line drops from either the vertical or horizontal direction. Unique hinge design assures correct alignment of contacts when the fuse holder is closed in from any angle.

and has a 250-mva interrupting capacity. Furthermore, the new device has the brain power of a recloser, combined with the muscles of a circuit breaker.

The new unit was developed for application on the Consumers Power Company system. Performance of the unit is much like that of a low-voltage recloser; the device operates with three reclosures, four trips, and a lock-out after the fourth trip. The recloser tripping is adjustable from 150 to 400 amperes. The interrupter portion is based on that used in the 115-kv, 1000-mva breaker described last year.

Mechanically, the device resembles a circuit breaker in that it is latched-closed under spring tension, so that the tripping device will unlatch the spring and cause the breaker contacts to open. This differs from usual low-voltage reclosers, which are normally spring-biased to the closed position, and are opened through a linkage mechanism actuated by a series coil during fault currents.

Another first for the 46-kv recloser is the use of transistors in supplying voltage to protective relays. Voltage signals are taken from a tap on each of the condenser bushings and amplified with a transistorized device. The output of the amplifiers supplies polarizing potential to the directional elements at the phase-and-ground type CR directional overcurrent relays. The transistorized bushing potential device is composed of all static elements for reliable long life, and eliminates the need for potential transformers. The device is mounted with the protective relays in a separate outdoor relay cabinet. ■

metal-clad ratings increased

■ As loads on large metropolitan substations grow, so must the interrupting capacities of the magnetic metal-clad breakers that serve these loads. Last year, 13.8-kv breaker interrupting ratings jumped from 500 to 750 mva. Almost before the ink could dry on these designs, ratings were jumped again—this time to 1000 mva. The new breaker (150DH1000) will have a continuous-current rating of 1200 or 3000 amperes.

The first of the 1000-mva units are being built for the Union Electric Company of St. Louis.

Low Voltage Too—The DB line of 600-volt magnetic air circuit breakers has similarly been extended from 75 000 to 100 000 amperes interrupting capacity; continuous-current rating from 3000 to 4000 amperes. This permits the use of a breaker measuring 34 inches wide by 45 inches high in place of another type breaker of this rating that measures 48 inches by 75 inches high.

While they were at it, engineers also made design improvements in the DB line. For example, the door can now be closed with the switch in either the "test" or "disconnected" position. This allows the user to de-energize the breaker during maintenance periods, and still close the front door, keeping aisle space open and the unit dust tight. ■

resistor assembly for disconnect switch

■ Disconnect switch operations on 345-kv lines can result in high-voltage surges, possibly high enough to trigger lightning arresters. To eliminate this problem, switchgear engineers have designed a special resistor assembly that mounts directly on the jaw of a disconnect switch. When the switch arm opens, it brushes past contacts of the resistor assembly, thereby inserting resistance (in three steps) into the circuit to damp out the high-voltage surges that could otherwise result. When the switch is closed, the opposite results; resistance is inserted into the circuit in three decreasing steps until final contact is made. ■

MEASUREMENTS, DISPATCH, PROTECTION

economic dispatch computer

▪ The economic dispatch computer is now installed and operating on the West Penn Electric system at their dispatching center at Charleroi, Pennsylvania. The computer will help direct the dispatch of power over the entire West Penn Electric system, composed of three principal operating companies —West Penn Power Company, Monongahela Power Company, and Potomac Edison Company.

The dispatcher uses the computer to determine and assign loads to generating stations that can carry it most economically, taking into account both generation and transmission costs. The computer represents generation in eleven major steam stations and one hydro station of the West Penn Electric Company's system, plus five tie lines to neighboring utility systems.

The computer operates by solving a group of simultaneous economic dispatch equations for the system. Four hundred potentiometers represent loss characteristics of some 1678 pole miles of 132- and 69-kv transmission lines. Station costs and constants of the transmission system are set into the computer. Station incremental production cost curves are selected for each of the units in service. With all of this information set into the computer, including upper and lower limits of power delivery for each of the various generators, the operator need only set the total required generation. The computer automatically positions itself to show the optimum dispatch of power for each of the generating units on the system.

Prior to development of the economic dispatch computer, the only way to get an economic dispatch was to ignore transmission losses, or to solve the economic dispatch equations for 15 or 20 values of system load, ranging from light to heavy. Loading curves were plotted for each generating station or unit. However, the family of dispatch curves were based on fixed quantities—specific values for fuel costs, availability of units, dispatch of power in the tie lines, and other considerations. Consequently, new curves had to be made every six months or so to reflect changing fuel costs and system conditions. With the economic dispatch computer, system losses are accurately considered without precalculated dispatch curves. The computer, located in the dispatcher's office, is kept continually up-to-date with system costs and availability of units. Hence, it gives a more accurate answer and obviates frequent restudy of the problem. ▪

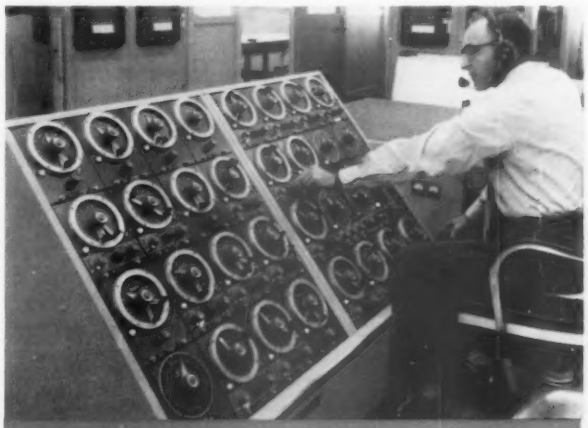
new annunciator system for generating stations

▪ An annunciator system with no moving parts for utility generating stations will get its first application in 1958 when the Public Service Electric and Gas Company of New Jersey employs it to monitor 560 critical quantities in their new 580-mw Bergen station. Designed to use modular plug-in magnetic elements rather than relays, it will be similar to Cypak static control systems introduced in 1954 for industrial control applications. However, circuit components are different. Static annunciator systems house several information-processing components in a single plug-in module; standard industrial systems require several modules.

Advantages of the new annunciator system center on the extremely long life and reliability of magnetic elements, but its designers list others of significance. They include: better testing—pressing a single button puts all of the logic elements in an 80-point system through a complete cycle, including the lamps, bell, and buzzer; low power requirements—1 watt per monitor point on standby, 8 watts when lamp is lit; and inherent "memory," which enables the equipment to resume proper indication after a power outage. Also included is electrical isolation of monitor signals, the ability to function over a voltage range of 75 to 140 volts, and the ability to convert the system for normally-open or normally-closed operation, simply by installing a different control module.

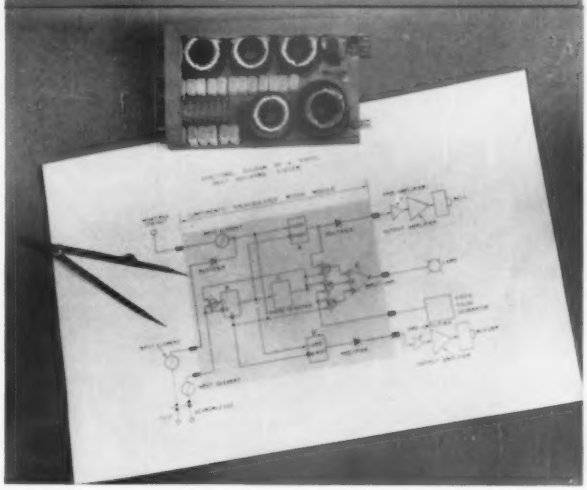
As designed for Public Service Electric and Gas Company, the system brings five hundred and sixty 115-volt inputs to the relay room, where each of seven cabinets houses a separate 80-point alarm system. (These are in turn arranged in 20-point subgroups; any subgroup can be removed from the system by a single switch.)

Bells, buzzers, and lamps for the system will be installed in the control room, one floor above. Under a "ring-back" modification specified by Public Service Electric and Gas Company, an incoming alert signal initiates a visual indication—a flashing lamp—and drives a bell, as the first of two audio indicators. When the alert is acknowledged by the control room



Above—This economic dispatch computer is operating on the West Penn Electric system.

Below—By encapsulating information-handling components in a single module, designers of static annunciator systems achieve plug-in installation. Shaded area in the photograph comprises components for a single monitored point.



pushbutton, the flashing lamp becomes steady and the bell is silenced. Whenever the cause for the alert is eliminated, the lamp begins to flash again and a buzzer sounds a second audio signal. Upon acknowledgement of the corrected condition, lamp, bell, and buzzer return to standby.

The basic system is designed to permit modifications desired by individual utilities. Among these are provisions for lock-in operation to signal occurrence of conditions as brief as two cycles; for lamps that glow continuously at low candlepower to permit spotting burnouts; and operation without ring-back, with one audio signal only. ■

transistorized voice adapter for type KR carrier

■ Electric utilities all recognize the importance of continuous service to their customers. Type KR (completely transistorized) power-line carrier for protective relaying helps utilities provide this service. To aid in installation and initial adjustment of this equipment, and for voice communication between power stations in emergencies, a transistorized voice adapter is now being produced.

The voice adapter is a plug-in unit that can be conveniently plugged into a socket on the carrier set for limited use, where frequent use is unnecessary or undesirable. It is economical because one adapter can be used with several transmitter-receivers. Complete transistorization of both transmitter-receiver and adapter minimizes the need for maintenance and provides a high degree of reliability. Besides being one of the smallest voice adapters available, the extra burden on the power source is less than one-tenth of an ampere, which occurs only when the unit is plugged in.

Protective relaying being the primary function, the circuits of the type KR transmitter-receiver and voice adapter are such that the relaying functions automatically and instantly take preference over voice communication. If supervisory control is used, it also takes preference over voice communication. In cases where close channel spacing is unimportant, the voice adapter unit can be used more frequently for station-to-station communication. However, it is not intended to be used as a channel for routine voice communications because of its narrow band width and the resultant audio response. ■

frequency telemetering

■ Wherever proportional electrical intelligence is to be transmitted over distances great enough to occasion power loss or expensive line construction, telemetering systems serve admirably. An improved telemetering system of the frequency type permits any electrical or physical quantity to be telemetered over multiplex channels carrying audio tones, power line carrier, or microwave. It is compatible with converting or transducing devices producing a direct-current output within a range of 0 to 400 millivolts, full scale.

At the transmitter, transducer output is converted proportionally over a frequency band ranging from 15 to 35 cycles, for modulation of the channel multiplexing equipment. At the receiving station, where the varying signal frequency is reconverted to a proportional d-c quantity, receiver output can operate such display devices as direct-acting indicators or recorders. With previous equipment, potentiometric recorders were required. Receiver output is 5 milliamperes full scale into a 700-ohm load.

Improved performance, increased circuit stability, and simplified maintenance result from advanced circuit design. "Hard" tubes have replaced thyratrons and so eliminated a major cause of drift and system failure; also adding to reliability are overall feedback in the transmitter, and saturating magnetic cores for frequency detection. ■

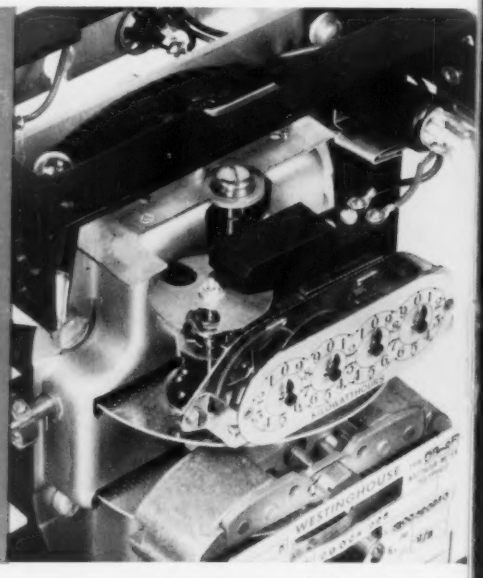
directional-distance relaying

■ New K-Dar compensator relays (Type KD) for directional-distance relaying on transmission circuits use two units per zone for complete phase fault protection. One unit protects against phase-to-phase faults, and another protects against three-phase faults. Neither unit is assigned to a particular phase. Previously, three relays were required—one per phase—with three impedance units, one directional unit, and a timer in each relay.

The system draws its name from the compensators that are its major components. Compensators—essentially air-gap transformers with current-energized primary—produce a current-derived secondary voltage that is added vectorially to the

Left—This transistorized voice adapter for Type KR power line carrier will help utilities provide continuous service.

Right—The Type CV impulse device generates impulses as equidistant gaps in a rotating brass disc pass between the coils of a transistor oscillator. Thus, impulses having specific watthour or varhour value are obtained to operate control equipment or provide input to impulse-operated demand recorders.



system voltage at the relay location. Resultant voltage energizes a high-speed induction cylinder unit that develops closing or opening torque, according to type and location of the fault.

In KD systems, full protection for one zone is afforded by one phase-to-phase and one three-phase unit in a single case. For three-zone protection, three such relays are required. Each relay case contains necessary transformers, tap plates, and auxiliary components for adjusting the relay. A separately mounted a-c timer provides the time delay for tripping zone 2 and zone 3. ■

meters needn't be prime movers

■ In a number of industrial and utility applications, impulses having specific watthour or varhour value are obtained from a watthour meter to operate control equipment or provide input to impulse-operated demand recorders. Formerly, such meters generated impulses from the opening and closing of mechanically driven contact fingers. Since motive power was that of the rotating meter disc, the friction load on the meter was a disagreeable necessity.

Recently, an ingenious application of transistors made possible elimination of both the friction load and the fragile contact fingers. The Type CV impulse device generates impulses as equidistant gaps in a rotating brass disc pass between the coils of a transistor oscillator. (Torque to drive the disc is supplied from the meter disc shaft through gearing.)

Since solid sectors of the vane prevent oscillation and open sectors permit it, current drawn by the oscillator varies in synchronism with rotation.

These current changes are fed to an externally mounted output relay that produces amplified impulses, which can be totalized, transmitted to remote control locations, or registered on demand recorders.

Advantages of the device stem from its minuscule frictional load and its nonreliance on delicate contacts that require painstaking adjustment. It also permits higher impulse rates, smaller impulse values, and consequently greater accuracy. The only basic limitation is that operating temperatures should range between zero and 150 degrees F; if lower temperatures are likely, specially modified units are necessary.

The development is capable of a substantial enlargement of the scope of impulse metering. Type CV impulse devices are applicable to all standard types of watthour meters and can be applied to kva demand meters to obtain kva-hour impulses for load control. Friction-free demand alarm devices also have become quite practical.

The first major application of the device was for load control in a steel mill having a base contract demand of 100 000 kva. Four supply circuits were totalized for an impulse-operated kva demand recorder. Kvah impulses also operate a demand limiter that signals an alarm if the rate of power usage exceeds the ideal rate. The system has been in operation since February, 1957. ■

switchboard and panel-type instruments

■ Users of switchboard and panel instruments will benefit from developments incorporated in two new products. To engineers responsible for panel layout, the magnetic shielding built into type X-35 d-c panel instruments will be welcome indeed.

By using a molded permanent magnet enclosed in a soft-iron outer ring, designers achieved instruments of the D'Arsonval type that are remarkably indifferent to ambient magnetic fields: they require no change in calibration whether mounted on magnetic or nonmagnetic panels, they can be mounted very close together without danger of interaction, and their susceptibility to external fields is minimal.

New indicating instruments for switchboards boast an eight-inch dial and a 250-degree scale; together, this means that pointers on Type K-26 instruments sweep across a 14-inch arc for full-scale reading. These instruments have four times the frontal area of their predecessors. The obvious advantages of the oversize dial is long-distance readability—an important virtue as switchboards continue to grow. Equally important, these instruments operate with the one-percent accuracy of smaller instruments.

Type K-26 instruments will be built to meet all standard ASA specifications in preferred ratings for measurement of volts and amperes (a-c and d-c), a-c power, synchronism, frequency, and power factor. ■

A survey conducted among hundreds of engineers and operating men from utilities and industry made evident the modern concept of the ideal circular-chart recording instrument. Designed as a direct result, the new Type 45 weatherproof instrument—in both switchboard and portable models—will include almost every suggestion.

The rustproof and corrosion-resistant aluminum alloy case can be flush or projection-mounted or equipped with a handle for portable use. No dust or moisture can penetrate the neoprene seal between the cover and case; a closed terminal housing makes the meter completely weatherproof. It is well suited to outdoor use on powerline poles and similar rugged applications.

Inside the case, a synchronous motor or 8-day hand-wound clock provides extra-high torque for one-, three-, or seven-day operation. A sealed plastic ink supply allows a continuous flow up to a year through a platinum-iridium pen tip. This is the first application of a sealed inking system to a direct-acting recorder.

Maximum efficiency and low energy consumption are obtained with a close magnetic coupling movement—the loss at full scale being 4.1 volt-amperes on ammeters and 10.2 volt-amperes on volt-meters at rated voltage. Self-contained ratings extend to 20 amperes, and 700 volts a-c. Rated accuracy of the Type 45 recorder is 2 percent. Momentary overloads up to one hundred times full scale deflection on the ammeters will not damage the instrument; spring mounts for the sapphire jewel bearings minimize the effects of shock and vibration.

3

APPLICATIONS OF POWER

This giant 8000-horsepower electric motor, largest ever made in the West, is pictured under construction. Through the stator opening, the rotor can be seen as it nears completion. The motor, weighing nearly 94 000 pounds, will be installed on a "cutter-type" dredge being built for the Utah Construction Company. The motor will drive a suction pump to lift sand and gravel from harbor or river bottoms.

STATIC CONTROL SYSTEMS

cypak for industry

■ Since their debut in 1955, Cypak static switching systems have chalked up many firsts as engineers in industry put the new control concept through its paces. Although exploratory applications continued throughout 1957, there was a shift in emphasis from trial to large-scale application. This is particularly true of basic industry; in 1957 major applications of Cypak control were made to critical operations in the steel, automotive, food processing, and lumber industries, to single out a few.

Cypak Feeds Blast Furnace—In late 1957, final adjustments were made on an automatic blast furnace programmer at U. S. Steel's Ohio Works. This is the first major Cypak control installation in the steel industry, and in terms of logic elements, is probably the largest system built for any purpose.

Blast furnaces produce iron by the continuous reduction of ore and the removal of impurities. For this, it is necessary that the basic solid materials—ore, stone, and coke—be added at the top of the furnace. These materials must be delivered according to a definite program by small gondola-like cars known as skips. Current practice requires a skip hoist to deliver one skip of material every minute. Since a furnace is expected to operate continuously for a period of two to two and a half years, controls that sequence these operations must have near-ultimate reliability. The function of the Cypak system is to charge materials into the furnace automatically and according to pre-selected sequence, of up to 20 skips. It will also sequence and control the operation of the coke bins, screens, conveyors, and feeders and gates that charge the skip. The large and small "bells" at the top of the furnace, which actually control the dumping of the charge into the blast furnace, will likewise be operated by the Cypak controller. The program sequence will be preset with pushbuttons and the cycle can be repeated as long as desirable.

One of the basic advantages of the new unit is that all elements are static, and therefore will not be affected by atmospheric conditions. The Cypak system replaces conventional relays, motorized switches, and telephone relays which have been in general usage for several years. Since the initial order of two Cypak controllers, three more have been ordered for installation this coming year.

High-Capacity Storage and Conveyor System for Cake Mixes—The first major application of Cypak to the food industry

was made at Chelsea Milling Company's new pre-mix food plant at Chelsea, Michigan. Here the problem was to provide for automatic sorting and conveying of over 40 000 cartons (350 tons) per day of 30 products ("mixes" for home baking) into 72 "on conveyor" warehouse storage lines, ready for selective shipment to four shipping dock areas. The cartons come from a three-shift operation, but since transport carriers normally provide pick-ups only during the daylight shift, an on-storage conveyor system of 11 000 feet was provided for temporary holding of second and third shift production.

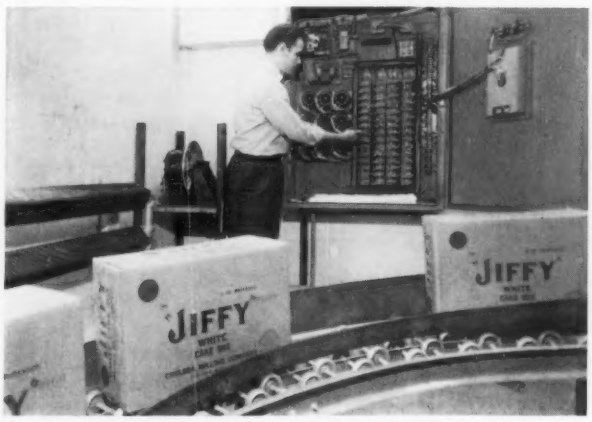
A Cypak director system was selected to direct traffic by the consulting firm of Bosch and LaTour of Cincinnati, Ohio, designers of the system. Briefly, the conveyor system takes the output from three production areas, sorts the resultant cartons into products, and stores them by product into the respective on-storage conveyor magazines. The Cypak "brain" for the system is a completely static control, thereby providing the reliability and maintenance-free operation demanded by this highly automatic warehousing system.

Pushbutton Sawmill—A lumber mill recently placed in operation at Orange, Texas, by the Lutcher and Moore Lumber Company, makes extensive use of Cypak static controls and other up-to-the-minute equipment to achieve a very husky reduction in the labor content of its product, one- and two-inch premium boards. The production of 1000 board feet of lumber requires the investment of only about eight manhours; for older mills, the conventional value is in the neighborhood of 26 manhours per thousand. As operations continue, Lutcher and Moore management hopes to reduce labor content still further, to perhaps six manhours.

In general, function of Cypak is to control the routing and spacing of lumber after it has passed through either of two ripsaws, one of which saws horizontally, the other vertically. Systems for both saws are practically identical in function. After a large piece is ripped in half by the vertical resaw, the two resulting boards leave the saw riding on edge and in very close contact; the two are automatically separated to permit subsequent automatic operations.

A second Cypak control is applied to permit the operator to return any excessively thick board for another pass through the vertical resaw. As this operator monitors the flow of boards—which normally pass in pairs—he determines whether one or both pieces should be resawed. To return these as infeed to the saw, he need merely press proper pushbuttons; Cypak controls thereupon reroute the specified boards to the saw for another pass.

One of several Cypak panels that control the sorting and conveying of baking mixes.



After lumber is passed through the horizontal resaw, a third Cypak control manages the sorting of good lumber from non-usable material. Here again sawed pieces are conveyed past the inspection point in pairs—usually as a bark-covered slab riding on a good board. The function of Cypak control is to initiate the discard of the slab. However, if both upper and lower boards are good, the operator presses the "No Waste" pushbutton and the normally prevailing automatic discard is suspended. If a series of pairs of good boards is approaching, a selector switch can be set to avert discard as long as desired.

Cypak Controls for Synchrotron—There is no room for error in the controls of high-energy particle accelerators such as the 30 bev (billion electron volt) alternating gradient synchrotron now under construction at the Brookhaven National Laboratory. In this system, a 5500-hp wound-rotor induction motor will drive a flywheel motor-generator set that delivers power to the synchrotron magnet. This large magnet will serve in turn to guide the particles to their final high-energy state. The motor-generator set must deliver power in pulses starting at zero and rising smoothly to a peak of 30 000 kw in 1.16 seconds, every 3 seconds. This calls for dependable controls on the flywheel motor.

To do this, motor torque will be controlled by a slip regulator whose current limit is controlled by a specially-designed Cypak sampled data regulator. The regulator compares the flywheel set recovery speed with a reference at the beginning of each pulse and alters the torque limit to control the motor input to the system for each cycle. It does this by driving a small motor-operated rheostat up or down in small increments, whenever recovery speed varies. This rheostat controls the current limit of the slip regulator and hence the average torque of the motor.

This high-power, cycling-type control lends itself particularly to use of static components that never wear out or deteriorate, as would relays if applied in this case.

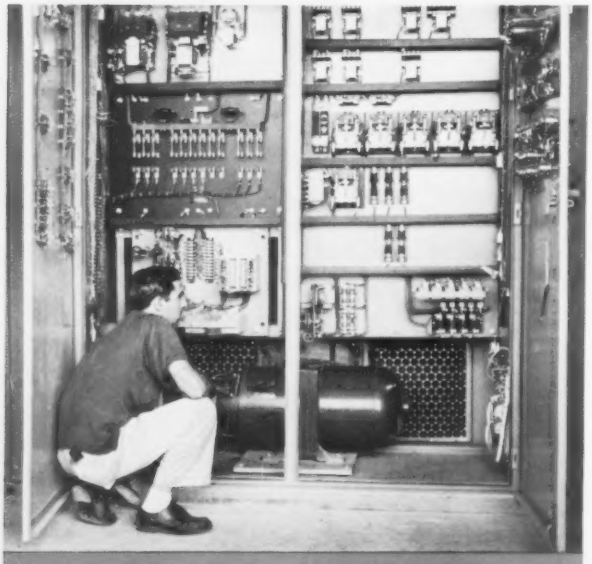
Static Proximity Limit Switch—One of the most common and important components of control systems is the limit switch. Although present limit switches are designed to operate without failure for millions of cycles, this is a relatively short period in the operation of high-speed automatic machines and process equipment. In addition, industrial atmospheres, vibration, and mechanical shock further reduce the reliability of the conventional contact-type limit switch. A limit switch whose life is practically independent of the number of operations performed has become a virtual necessity.

A contactless proximity switch has been developed which utilizes a variable-reluctance bridge-type circuit for sensing and is reasonably independent of voltage and temperature. It provides true electrical "snap-action," which is an exclusive feature not found in other similar devices.

When a piece of magnetic material is brought within the trip distance—variable up to a maximum of ½ inch—the bridge is unbalanced and its output fed to the control element. The signal caused by the unbalanced bridge is converted to a true digital output and can drive Cypak components or can drive 24-volt d-c relay or solenoid coils with a maximum power demand of 8 watts. ■

magamp controls for anode casting

■ What does it take to control this system? A 1200-rpm motor geared down to 0.24 rpm must rotate a loaded wheel 25 feet in diameter weighing 50 000 pounds, accelerate it from



Top—A Magamp system controls this process for casting molten copper into anodes for further refining.

Bottom—Each a-v drive cabinet contains m-g set and control equipment for a conveyor at Chrysler Corporation's automobile assembly plant at Newark, Delaware.

zero to "top speed" in 10 to 25 seconds, adjustable, and decelerating it at the same rate. The drive must do this job smoothly without any jerking in starting or stopping. The problem was solved by using a Magamp system with rate-of-change feedback to control the system's generator field current.

This unusual problem arose in the casting of molten copper into anodes for further refining. In the process, the large wheel mounts ten equally spaced molds (24 by 30 by $\frac{5}{8}$ inches) around its periphery. During a complete revolution, a mold is filled with molten copper that solidifies to form the anode, the anode is removed and the mold is reconditioned to receive the molten copper again. In the process of casting, all starting, stopping, acceleration and deceleration must be smooth, because any jerking or sloshing motion will disturb the crystal structure of the cooling copper and cause problems in the electrolytic processes that follow.

In the control cycle, the wheel runs at 0.24 rpm after accelerating, until a limit switch initiates the slowdown and takes about 10 to 25 seconds to decelerate to 0.024 rpm. The wheel runs at this slow speed until another limit switch applies a suicide field to the generator to bring the wheel to a complete stop. A complete cycle from start to start takes $1\frac{1}{2}$ minutes. The system was built for the Inspiration Consolidated Copper Company, Inspiration, Arizona. ■

automatic conveyors for automobiles

■ Motor and control equipment applied to the Chrysler Corporation's highly automated automobile assembly plant at Newark, Delaware, does a great deal to minimize manual material handling. At this plant, floor conveyors and overhead conveyors are synchronized to travel in unison and transfer of bodies from one conveyor to another is entirely automatic. Even the transfer of body trucks from the normal assembly line to inspection and repair lines requires no manual assistance after the attendant operates a pushbutton.

Serving as nerve center for the electrical intelligence system that directs the synchronization of each conveyor with its lead conveyor is a Magamp magnetic amplifier, which regulates conveyor speed and position. A polyphase synchrotie transmitter driven by each conveyor transmits an accurate position signal to the magnetic amplifier. Here the signal is compared with a similar electrical position signal generated by a master synchrotie driven by a second, or lead, conveyor. Conveyor dogs spaced from 16 to 18 feet apart along the conveyor chain are thus controlled to meet the position of dogs on a second conveyor within one inch. This provides safe, dependable transfer as a body truck passes from one conveyor to the next.

Each conveyor is driven by one, two, or sometimes three d-c motors; all are powered from one adjustable-voltage generator. Control equipment is selected to complement motor characteristics so that each motor assumes proper load according to conveyor configuration and the location of each particular drive. The generator and its driving motor are packaged with the control equipment for one conveyor into a single factory assembled a-v drive. Magnetic amplifiers were selected as regulators because they are static amplifiers having long virtually trouble-free life. Shock and vibration resistant, they require no warm-up time.

The entire assembly plant is arranged to follow a selected master rate signal. However, for flexibility the plant area is divided into several zones and a zone master signal control is provided. The conveyors in a particular zone may be designated to run at some slightly different speed than the plant master, even one-half speed or double speed if paralleling assembly lines are added or removed from operation in the zone.

One of the indicating instruments on the front door of each a-v drive cabinet is a synchroscope, which is connected to indicate the instantaneous relative position of the two conveyors being synchronized by the control equipment in that cabinet. An electrician on duty is able to look at the synchroscope and detect any variation in performance and to determine more about the accuracy of synchronization than can the personnel out on the actual assembly line. A minor or trimming adjustment is available to the electrician if he should need to make an adjustment. ■

compensating for friction and windage

■ Several new electrical features appear in the aluminum rolling mill placed in service at Ravenswood, West Virginia by the Kaiser Aluminum and Chemical Corporation. For one thing, magnetic amplifier regulators will be employed throughout the mill.

One particular feature is the control equipment for two foil mills, which will roll strip varying from 27 to 56 inches in width. The control equipment provides for compensation for

friction and windage losses in the reel circuits. This is accomplished with a pilot generator on the reel motor, which feeds a signal into the current regulator so that the current value regulated is increased to approximate the friction and windage losses in the drive. This compensation is of considerable advantage since the current required to overcome the friction and windage losses varies with reel rpm and becomes a substantial portion of the total current required to operate at the desired tension, particularly when narrow, thin foil is being rolled. ■

MOTORS AND CONTROLS

progress in motor design

■ For users and builders of industrial motors, 1957 was an unusually fruitful year. Important developments include the introduction to industry of several new special-purpose types—both a-c and d-c—an upward extension of frame sizes in which "work-horse" Life-Line A squirrel-cage motors are available, and the announcement of an important new line of d-c motors and generators.

Life-Line H Industrial Motors and Generators—Designed for utmost compatibility with today's automatic production equipment, these new d-c machines have drip-proof enclosures as standard and bear NEMA Class B ratings. As motors they are rated from 1 to 150 horsepower and as generators from ¾ to 100 kilowatts. The designers can boast of several "industrial firsts." Among these are the use in standard industrial machines of a high-temperature silicone insulation system on machines rated to operate within Class B temperatures; a ventilation system that draws air from the drive end and controls its distribution within the machine; and a new housing construction that enables drip-proof machines to serve many applications previously requiring splash-proof machines. Of special importance to control engineers who integrate d-c motors into high-production systems are the vital statistics applying to response. Because of a marked decrease in armature inertia (up to 55 percent) and improved commutating ability (up to 35 percent), Life-Line H motors are capable of the fastest dynamic response yet available from standard machines.

Completion of NEMA Re-Rate Program for Squirrel-Cage Motors—With the availability of three new diameters and six new frame sizes (354U through 445U) for Life-Line A type "A" open drip-proof and TEFC a-c motors, Westinghouse has accomplished its objectives within NEMA's program for re-rating polyphase industrial motors. With this program complete, designers can re-design and re-rate motors larger than those covered by NEMA standards.

In superseding the Type CSP drip-proof and Type CS dual-vent fan-cooled motors in ratings from 40 to 125 horsepower (at 1800 rpm) the new motors incorporate many advantages for the user. Among these are greater compactness, improved physical protection, and higher thermal capacity.

Production facilities for the new sizes are unique in that they include the first really automatic machines for machining large and basic motor parts on a high-production basis. ■

longer rotor core saves space

■ A pair of d-c motors, the twin drive for a reversing slabbing mill for hot steel slabs, have the longest rotor cores—each 75 inches—of any d-c motor built by Westinghouse; yet, they save space. How? Because one motor drives the upper roll of the mill, and the other the lower roll, the motor diameters are limited, thereby requiring long machines. D-c machines of this length normally employ two armatures in tandem with two commutators and end turns for two cores. Since space limitations also made a shorter machine desirable, the result was the single-rotor core—cutting down on the space required for commutators and end turns—to shorten over-all machine length.

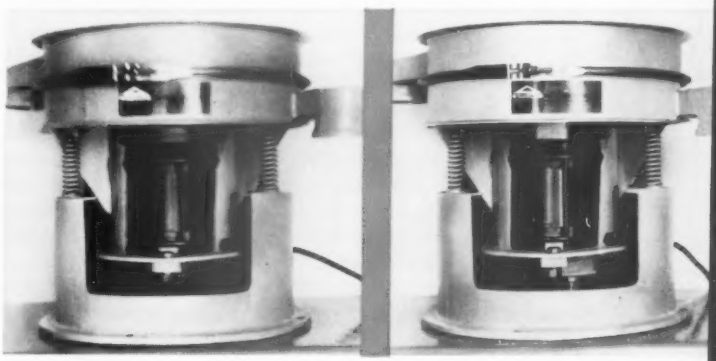
These machines are installed in Republic Steel Corporation's new 45 by 90 inch reversing slabbing mill in Cleveland, Ohio. Each machine is rated 6000 hp, 700 volts, and 40/80 rpm. D-c power is supplied from four 2500-kw generators on a seven-unit flywheel motor-generator set. ■

'rock 'n roll' motors for industry

■ Although most electric motors are expected to run smoothly and silently, unusually sturdy little electric motors scorn these staid virtues. These motors, destined to shake violently for life, are made in one-fourth and one-horsepower sizes for driving Sweco "Vibrating Screen Separators," used for screening and separating tasks in many industries.

In operation, the separators receive material on vibrating screens of the desired mesh. Depending upon the specific job, desired or unwanted parts of materials may be retained on the shaking screens or passed through the fine mesh.

The shaking and tumbling motions necessary for screening and separating jobs are produced by eccentric weights attached to both ends of the motor shaft, which is mounted directly below the screen. Location and mass of these weights determines direction and degree of the screen motion. Spring mountings prevent vibration of the motor-screen assembly from being transferred to the separator base, hence to the room or building in which the machine is used. ■



Motors that drive these Sweco "Vibrating Screen Separators" are destined to shake violently (left) for life.

improvements in papyrus

■ *Big Helper*—"Helpers" are required on cylinder paper machines to relieve tension on the felt, which picks the wet pulp from the cylinders and carries it onto the press rolls. By employing helpers on the cylinders and the press rolls, the average felt life can be increased about 25 to 30 percent.

The largest helper drive for a cylinder machine is now installed on the widest cylinder machine in the world at the Whippany Paper Board Company. A total of 14 motors, 8 on the cylinder rolls and 6 on the press rolls, put driving torque into the wet end of this cylinder machine.

Biggest D-C Drive—The largest single d-c drive yet installed is going into the Enso-Gutzeit mill in Finland. Two 1250-hp motors will be directly coupled, providing 2500 hp to drive the line shaft of a newsprint machine.

Fastest Winder—As paper-making processes speed up, equipment that handles paper for trimming and rewinding must also step along. The world's largest, fastest winder, scheduled for operation in 1960, will operate at 7200 fpm at the Savannah plant of the Union Bag-Camp Paper Corporation. ■

heavy-duty limit switch

■ Limit switches are widely used to initiate signals in accord with position changes. Because of this wide applicability, field modification is often highly desirable.

Designers of new Type HDH limit switches have combined versatility with electrical and mechanical ruggedness. Made as single- or two-circuit devices, the switches can be converted from normally-open to normally-closed operation—or vice versa—simply by rotating the operating cam on its shaft. Also, the switch will respond to either clockwise or counterclockwise actuation of the operating lever. Position of the operating lever can be reversed to the opposite side of the case. Cases can be equipped with cover and shaft seals to make the equipment dust and water tight.

Viewed electrically, permanent magnet blow-outs enable the new equipment to rupture highly inductive circuits; on d-c, they can handle up to 2 amperes at 250 volts and 1 ampere at 600 volts. On d-c resistive circuits, they are rated 25 amperes at 250 volts, 10 amperes at 600 volts. A-c ratings are 25 amperes at 220 volts and 15 amperes at 600 volts. ■

geared for mountain moving

■ The heavy earth-moving equipment operators of yesteryear could throw a mighty fast speed shift. But recent developments in transmissions place the most skilled of the old "clash-box" school in a back seat position when it comes to rapid ratio changes. A combined gear box and torque converter reduce the task of shifting to effortless lever pressing.

In addition to the work-saving features, the new transmission reduces long-term operating expense. The torque converter keeps diesel engines running above a minimum predetermined speed when under load regardless of the speed at which the equipment is moving. Therefore, lugging is eliminated and longer engine life results.

Use of the torque converter allows fewer gearing steps. The Westinghouse motor-grader transmission is designed for engines that deliver up to 500 foot-pounds of torque and has four forward and four reverse ratios. This transmission and converter package replaces a conventional "clash-box" of 8 to 10 speeds. In units of horsepower at typical diesel speeds, this corresponds to approximately 200 hp. The only external pipes lead to a heat exchanger for the coolant, eliminating the pipe fitter's paradise by concealing the other pipes inside the housing, and making this the most uncluttered unit in the industry. ■

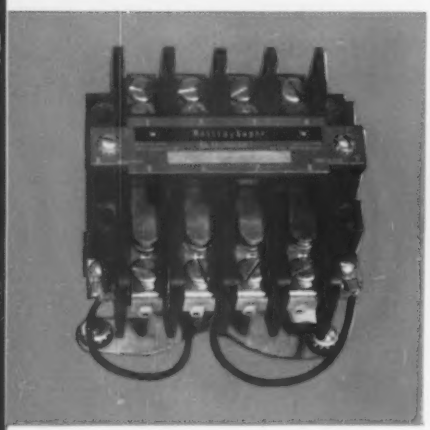
speed reducer demand brought mass production

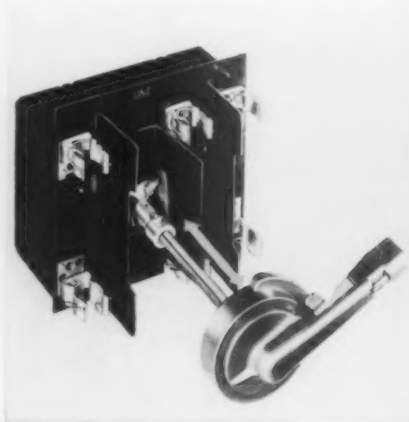
■ Manufacturing engineers, market research men, and sales personnel sat down with a crew of designers to work out the plans for a group of gearing products to please everyone. Until now, many units have usually been designed and built to order for particular applications and stock shipments were not possible. Ratio changing was difficult, and so was fast delivery. Emergency one-hour, and regular three-day order filling is only one of the advantages to the new line of helical-gear, speed-reducing units called Moduline. Basic subassemblies and accessories are combined to make any helical-gear drive configuration; use of parts common to a wide variety of configurations has made mass production, automatic machines and advanced manufacturing techniques possible.

The parts are stocked at the factory and in three other geographical areas so that subassemblies and accessories need only be bolted together into a self-contained unit to fill an order. A small inventory can maintain a large variety of gear-drive types through interchangeability; and an existing arrangement can be easily taken apart and rebuilt by the user for a different application.

Stock components are the building blocks for the gearmotors, separate speed reducers, and package motor (sugar-scoop) reducers. Standard components can be assembled into arrangements providing for floor, ceiling, wall or angular mounting. Addition of accessories provides further versatility for vertical flange mounting, right-angle input and output drives for gearmotors, package motor reducer drives, and speed reducers. By using the same basic parts, a hollow shaft and an aluminum cover, shaft-mounted reducers with any of the standard American Gear Manufacturers Association ratings can be put together.

The heart of Moduline is a double-reduction cage with a fixed 5-to-1 set of low-speed gears. Spin flame heat-treated speed change gears are mounted on rolled spline shafts so that they can be replaced with common hand tools. Gears in the triple and quadruple reduction subassemblies are also spline mounted. All gears are precision ground after through hardening and, in fact, meet AGMA standards for master gears. A total of seven unit sizes to 30 hp are available with ratios of 5-





Far Left—Motor contactors and starters like this one are part of a new line of magnetic motor controls. They are specifically designed for that type of motor load typified by air conditioner compressor motors.

Left—This new Visi-Flex Switch combines the features of visible contacts and flexibility of interchangeable fuse clips. It comes in two models—the model T with a toggle handle and the model A with an extendable handle mechanism for ease of mounting in panels of various depths. The new Visi-Flex Switch can be used as a fused or unfused device. The fuse clips mounted on top of the switch save the cost and space of separate fuse blocks, thereby simplifying installation and reducing panel space approximately 30 percent. The new switch is made in 30, 60, and 100 ampere ratings, with fuse clip kits available in standard ratings up to 200 amps, 600 volts.

to-1 to 625-to-1. Every Moduline unit can carry overhung loads for almost any type of power take-off using sprockets, pinions, or belts.

Almost 80 percent of all driven equipment is operated at speeds other than standard motor speeds. Reliability, safety, and economy of operation have made a place for geared speed reduction in industry. Moduline, with its ground-tooth precision, versatility, adaptability, wide range, inexpensive and easily changed variable elements, and fast shipment will bring even wider acceptance. ■

GAS TURBINES

new jobs for gas turbines

■ The industrial gas turbine is making many new friends in the process industries. Generally thought of as a prime mover, it has other abilities—such as the production of hot air. The versatility of the turbine makes it particularly adaptable to chemical process lines. As a result, many new "firsts" are appearing—in fact almost each new process innovation in applying the turbine becomes a first.

Gas Turbine "Gasifier"—In a large southwestern butadiene plant, four gas-turbine "gasifiers" are an integral part of the chemical process line. Butadiene, an essential ingredient in the manufacture of plastics and synthetic rubbers, is made from butane gas. Reactivation of a catalyst used in the process requires hot air at approximately 1200 degrees F. Each turbine will supply the equivalent of 98 000 standard cubic feet of gas per minute, at 1000 degrees F and 28.2 psia. The turbine will burn only a small fraction of the oxygen in the inlet air, so that the hot exhaust gas will still have an oxygen content of 18 percent. A relatively small heat addition is required to bring the gas up to the required 1200 degree F temperature.

The "gasifier" unit is a modified 7000-hp gas turbine. The process described utilizes all the heat rejected from the machine, making it the most efficient method by far for obtaining large volumes of hot gas at moderate pressures.

"Waste Heat" Not Wasted—Another application in a refinery utilizes a 5300-hp gas turbine. In addition to the power generated, 70 percent of the heat energy in the exhaust is recovered, which results in a high overall plant efficiency. The turbine supplies mechanical power to drive a centrifugal air compressor, which supplies process air to the catalytic cracking unit; the turbine exhaust gas is fed to a "waste heat" boiler, supplying heat for making process steam. Besides being efficient in operation, the gas turbine economically utilizes process gas, a by-product of the refinery plant, as fuel.

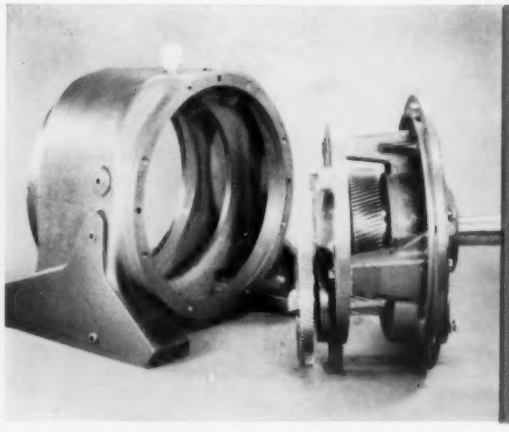
Several smaller turbines—3000-hp units—are going overseas for similar use in catalytic cracking plants. As of this writing, two are in operation in Japan, two in Sumatra, and one scheduled for Cuba. The adaptability of the modern gas turbine to the chemical process industry indicates that it has a bright future indeed. By utilizing the gas-turbine outputs —shaft power, compressed air, and heat—processes can be streamlined and efficiencies improved. Westinghouse gas turbines can now provide shaft power up to 22 500 hp, compressed air up to 85 psia, and hot gas containing 18 percent oxygen up to 1000 degrees F and 28.2 psia. ■

15 000-hp single-unit compressor station

■ A completely different type of gas compressor station has been put into service on the Texas Eastern Transmission System between Mississippi and Pennsylvania. The basic building blocks of the three new single-unit stations are: a 15 000-hp synchronous motor driving a single-stage centrifugal compressor through a 900-6506-rpm speed increaser.

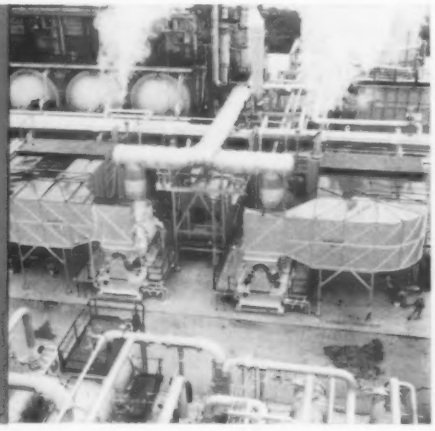
The 15 000-hp motors, largest in gas-transmission service, operate at 4160 volts and 1580 amperes full load at 900 rpm. To remove the excess heat from the motor, exciter, and collector, the motors are force ventilated by a 30 000-cfm blower with a spare, each driven by a 30-hp explosion-proof motor. Incidentally, this heat is used to heat the compressor buildings in cold weather. This motor delivers 87 500 foot-pounds of full load torque and since the motor-gear-compressor system is a relatively high inertia load, 43 000 hp-seconds of energy are delivered to accelerate the drive. The large motor windings alone contain 12 000 pounds of copper and have a total length of 10 miles!

Several problems arose in designing the 17 250-hp speed-increasing gear unit. Since a high stored energy in the gearing unit would make starting difficult, it was designed primarily for low inertia. This involved keeping the low-speed gear to a minimum diameter and reducing the center distance, while maintaining high-horsepower capacity. The final design was a heat-treated gear with a 34-inch wide face and a 42-inch center distance. Gearing engineers also reduced high-speed bearing spans and high-speed shaft deflection by designing three bearings for the high-speed shaft. The total weight of the gear unit is 45 000 pounds. In spite of the unit's large size, a special low-speed coupling limits the end float of the motor shaft to only 3/16-inch. Air-to-oil fan-type coolers provide cooling for the oil system without requiring any water. These



Left—Gear case and low-speed cage of Moduline unit (5:1 gear ratio).

Right—Gas turbine "gasifiers" have become an integral part of this butadiene process line.



units must operate in a potentially hazardous atmosphere.

Starting and stopping controls for these stations are completely automatic, initiated by a single pushbutton. This type of control is easily adaptable to remote supervisory control over microwave or common carrier systems.

Other features of these single unit stations, stressing simplicity in design, are across-the-line starting of the motor—and low operating cost.

Other equipment built for outdoor substations powering these installations includes a main circuit breaker, and Autovalve lightning arresters for the 161-kv incoming line, a 16 000-kva 161- to 4.16-kv transformer, and 5-kv outdoor metal-clad switchgear. ■

conservation island

■ Seven miles out on Lake Maracaibo, Venezuela, where the water depth is 90 feet, a gas conservation plant is maintaining pressure on the oil reservoirs. As the crude petroleum is brought up from the oil reservoir to the surface, natural gas comes out of solution. A portion of this gas is used to drive the gas turbines, which power compressors for injecting gas, compressed to 2000 psig, back into the oil reservoirs. This minimizes the pressure decline that accompanies the production of crude oil.

This conservation plant—the Tia Juana No. 2—of the Creole Petroleum Corporation is the world's largest industrial gas-turbine installation. Twelve gas turbines drive centrifugal compressors, pressurizing some 300 000 000 cubic feet of gas per day. The "island" is 440 feet by 131 feet, and is supported by 350 concrete piles, each 200 feet long and weighing approximately 90 tons each.

The fourteen additional gas turbines, which are now being built for a new Tia Juana No. 3 plant, will make it the largest when it goes into service. ■

HEATING AND WELDING

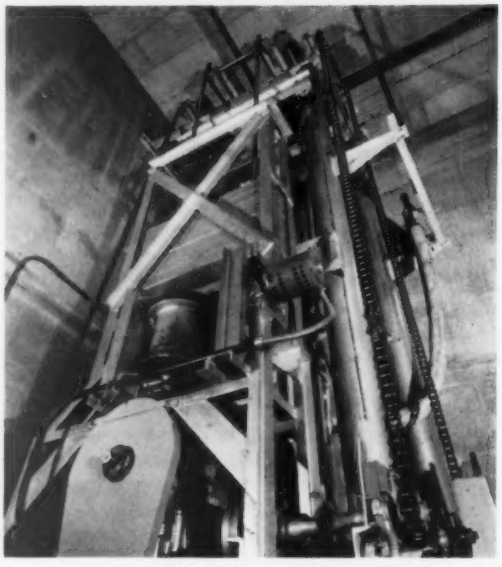
continuous annealing furnace

■ Recently, continuous annealing of tin-plate strip has become important because of the uniformity, greater stiffness, and absence of any sticky-edged strip (which slows down production) generally associated with the process. Material from a continuous-process furnace is more easily rolled in the temper-pass mill than batch annealed coils. One such large furnace has been installed in the Weirton Steel Company's Weirton, West Virginia mill. Weirton Steel Company is a division of National Steel Corporation.

This vertical multiple strand furnace is heated by gas-fired radiant tubes processing strip at a speed of 2000 feet per minute. It can handle 60 tons per hour, based on a strip one-thousandth inch thick and 30 inches wide. The strip is heated from room temperature to 1350 degrees F in a protective atmosphere to prevent ingress of small amounts of oxygen, with the average chamber temperature of 1650 degrees F. Basically, the furnace consists of four sections: (1) a gas-fired radiant-tube heat-up section, (2) an electrically heated soak section, (3) a slow-cool section with air-cooling tubes and electric heat, and (4) a water-cooled section.

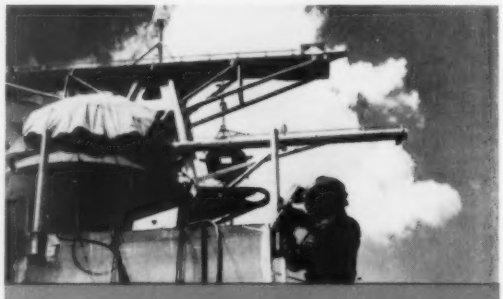
Trends in continuous vertical strand annealing furnaces point to a reduced number of passes required in the overall furnace cycle. The fast-cool section of this furnace, for example, saves ten passes by quenching the strip at 450 degrees F rather than cooling it down to 250 degrees F or less. Further improvements in cooling can shorten the amount of strip that must be stored in the furnace. ■

Gas conservation plant on Lake Maracaibo, Venezuela.



Largest commercially built vacuum arc melting furnace.

The Boeing 707 Jet Transport will have an electric power system designed specifically for commercial aircraft.



In shipyards, high portability is a must, particularly for welding equipment used aloft. Here at Bath Iron Works in Maine, a shipyard welder takes full advantage of a new Westinghouse handgun to weld an aluminum superstructure. Small box to welder's left is the control unit; at rear of gun is the integral one-pound wire supply.

induction heating for cable annealing

▪ Convenience and compactness of induction heating are providing it with new jobs. For instance, equipment has been ordered to stress relieve 7-strand steel cable used in prestressed concrete slabs. These cables replace the familiar reinforcing bars and also set up compressive stresses within the slab to counteract loading stresses. When casting the slab, the cables are placed in tension, the concrete is allowed to set, and the cables are released. For this service, cable must have definite physical properties, which 600-degree stress relief develops. Induction heating is applied in the cable forming line just before reeling. ▪

new use for 'nothing'

▪ The use of vacuum in industrial furnaces was only a laboratory curiosity a few years ago, but has now come into widespread use. Furnaces are being designed to take advantage of the protective properties of vacuum, and its purifying potentials.

Vacuum Arc Melting—The largest commercially built vacuum arc-melting furnace in this country has been built for the Carborundum Metals Company in Akron, New York. The consumable-electrode furnace double-melts zirconium metal to yield ingots 16 inches in diameter and weighing more than a ton. The vacuum-arc process eliminates crucible contamination by melting the metal electrode in a water-cooled copper crucible, preventing any chemical reactions. Many alloy steels can be melted by this method because of the improved properties obtained. In addition to gas removal by vacuum action, the process exhibits a cleaning effect by floating impurities to the top of the ingot, redistributing sulfides into a more uniform pattern, and better ingot uniformity through the rapid freezing rate.

Vacuum Heat Treating—In a standard hot retort furnace, heat is radiated from the heating elements to the retort, which in turn reradiates heat to the charge. This method of heat transfer is highly inefficient and retorts subjected to high heat have extremely short life. Since all heat transfer in vacuum is by radiation only (there are no gases to transfer the heat by convection), this radiation can be stopped with mirrors, or their industrial equivalent, radiation shields. Therefore, by interposing radiation shields between the heat source and a vacuum-tight retort, the retort can be maintained at a low temperature by means of water cooling. Furnaces of this type, called Kold-Retort vacuum furnaces, are made to operate at temperatures up to 4000 degrees F at high vacuum. One Kold-Retort type furnace, with a charge space of 4 by 4 by 12 feet, is in operation in the titanium industry. In addition to the inherent advantages, cycle times can be less than one-half those possible with similar sized hot-retort furnaces. ▪

for brazers, a new alloy

▪ Rarely are the words "sluggish" and "mushy" selected to describe the merits of a new product—but these qualities are useful indeed to engineers concerned with the flow range of a brazing alloy to be used on joints having poor fit up. Until the development of the Phos Silver 6M brazing alloy, virtually the only suitable alloy was a specific amalgamation of copper, phosphorus, and silver. To be effective this required the presence of 15 parts of silver in every 100 parts of alloy. And these days, silver comes high.

In contrast, the new alloy is much less costly, since it requires only 6 parts per hundred of silver. By limiting constituent phosphorus to 6 parts per hundred, the new alloy is more than equal to its predecessor in ductility and strength. Brazing temperatures range from 1275 degrees F for large gaps of, say, 1/16-inch, to 1350 degrees for tight fit ups.

The new alloys fall within AWS-ASTM classification "B Cup-3." Produced by extrusion from a two-story, 450-ton press, through dies shrouded by an inert gas, the alloy reaches the customer bright and clean and with exact chemical composition certified. ▪

MARINE AND AVIATION

aircraft electrical systems for jets

▪ Each year, significant advances are made in aircraft electric-power systems, both in the application of the equipment and in the technical state of the art. The trends established as a result of the developments made during the last few years—equipment designed for increased reliability by use of static components—have culminated in a modern electric-power system designed specifically for commercial aircraft. Its first major application will be on the Boeing 707 commercial jet transport, which will go into service early in 1959 in the United States, and early in 1960 in other parts of the world. The a-c electric-power system that has resulted is the most modern in existence. It will develop 120 kva of power at a frequency of 400 cps, at a controlled voltage of 115/200 volts. It will incorporate brushless a-c generators, with magnetic-amplifier regulator voltage control, and static control and protection provided by silicon diodes and transistors. The elimination of brushes and the extensive use of static devices have improved performance, increased reliability, and reduced the expected operating cost.

The first production Boeing 707 aircraft has now flown with four a-c generators operated in parallel. Behind this flight is an extensive engineering program to support commercial aviation with the latest technical advances. This program includes support from conception to usage. For example, industry will be provided with technical know-how where this line of aircraft equipment is being first used. Engineering Field Service is providing a maintenance-training program for personnel from the United States and abroad. The spare parts provisioning program will include consideration of world-wide operation.

Significantly, this program, from the completion of Boeing specifications in mid-1956 to completion of flight clearance tests, consumed less than 1½ years. This speed resulted from the use of a systems approach, implemented with computer studies and experience previously gained from research, laboratory tests, flight tests, and service operations in many of the past aircraft installations. ▪

J54 turbojet engine passes first tests

▪ The first American turbojet engine developed with private company funds, the J54, successfully completed its initial flight tests at the Flight Test Center near Kansas City. Suspended from the bomb bay of a B-45 flying test bed, the engine demonstrated stall-free performance at all scheduled test points over a broad operating range. Jam accelerations—where the engine throttle is quickly thrown wide open—were accomplished at altitudes more than 20 percent above the B-45's normal service ceiling, made possible by the additional power of the J54. In addition to flight testing, the engine has completed several hundred hours of static testing and test-cell performance verification, and high-altitude tests conducted in the altitude chamber at the Naval Air Turbine Test Center in Trenton, New Jersey.

Far Left—The J54 turbojet engine has been put through its paces, suspended from the bomb bay of this B-45 flying test bed.

Left—This is WETAC (Westinghouse Tubeless Airborne Computer)—the latest prototype analog computer developed for airborne use as a fighter armament control director. WETAC will automatically direct an interceptor on either a lead pursuit or lead collision course regardless of the type of armament, guns, rockets or missiles. Reliable operation in the airborne environment was the primary design objective. With ease of maintenance, flexibility, small size and weight, and cost, the unit was designed to demonstrate the compatibility of a new family of plug-in, tubeless, analog, computing components. WETAC is compatible with the line of interceptor radars and other electronic subsystems in the air weapon, including the autopilot.

Right—AEDC facilities at Tullahoma, Tennessee.

The engine is designed specifically to take full advantage of the lightweight properties of titanium alloys. Design goals for the J54 defined an engine in the medium-thrust class, which could be lightweight, efficient, durable, and economically produced using a minimum of critical material. These objectives required thorough analysis of all high strength-to-density materials. In some cases, certain steel alloys show distinct superiority over titanium alloys with respect to such characteristics as buckling strength and ease of welding. The final choice of material for each specific component often was necessarily based on a compromise between weight, reliability, and production economy.

Several versions of the J54 engine are possible—both afterburning and non-afterburning. The basic non-afterburning J54 is a single-spool, axial-flow, three-bearing engine in the 6000-pound thrust class.

Weight reductions and design advancements, prompted by materials research, can already be forecast for J54 jet engine development. ■

airborne improvements

■ The development of airborne autopilot and fire-control systems depends upon simultaneous developments and improvements along many fronts. Take for example, a sampling of last year's accomplishments:

SIR-1 Gyroscope—The SIR-1 miniature integrating-rate gyroscope is a second design in the development of miniature instruments intended primarily for application in fixed and flexible fire-control systems. It is also suitable for autopilots and missiles.

This design is an outgrowth of the XB-1 and XB-2 gyros and incorporates features that permit greater versatility in application. Among these features are: (1) a signal generator and a torque generator that do not have rotating magnetic material and its resultant hysteresis torques; and (2) an improved synchronous gyroscopic wheel motor.

Magnetic Modulators—A magnetic pulser is a pulse generator suitable for driving the radar transmitter magnetron. No tubes are required in the all-magnetic pulser. Its advantages are: no warm-up time required other than the magnetron; no tubes are required, and hence resistance to shock and vibration is greatly improved; efficiency is high; there is no limit to power-handling ability; and components are inherently reliable. Pulsewidths of 0.1 to 3 microseconds (or higher) are obtained. Repetition rates depend primarily on the available a-c supply. Peak power from 40 kw up to 8 mw are obtained. The device is being used in missiie application.

Hydraulic Antenna—A hydraulically-driven scanning antenna is being used in an airborne radar system. The hydraulic drive positions the antenna to the desired space position, determined by either the information received from the radar or from a search command system. Replacing an electric motor and gear-train system, the principal advantages of the hydraulic drive are: smoothness of operation, since the actuator is coupled to the antenna without the need of a gear train. and in the speed of response. Other advantages are: dynamic range, a range of velocities in the order of 24 000 to 1; speed of response, which can be made three or four times that of a comparable electric system; and the reduced amount of power required from the driving amplifier.

Transistor Servo Amplifier—A new transistorized servo amplifier provides amplification, stabilization and error signal conversion for a dual-antenna system, maintaining each antenna oriented in space regardless of roll deviations of the aircraft, within the limitations of the system. The amplifier uses seven transistors in each of two amplifier channels. The two channels and a common power supply are mounted on five printed-circuit boards. The amplifier requires about 1 watt of 115-volt, 400-cps power. Its main advantages are: small and compact—weighs 40 percent less than tube-molded unit and occupies 50 percent less volume; lower power—about one-tenth the power of previous versions, not subject to the effects of humidity; and ease of maintenance—open printed-circuit boards allow repair of defective circuits.

Magnetic Amplifiers—With increasing demand for smaller and higher performance amplifiers, the tendency in the magnetic-amplifier industry has been to rely on higher frequency power supplies. As a result, the fast-response magnetic amplifier (Hybrid III) was developed. These amplifiers eliminate the simple time delay associated with the commonly used full-wave amplifiers. For this reason their output amplitude remains essentially unaffected by signal frequency. In aircraft, and particularly in missile applications, the advantage to be gained by eliminating the additional complexity and weight of frequency multipliers becomes quite pronounced. For example, the 2400-cps missile flight control system weighs approximately 20 pounds while the 400- to 2400-cps frequency converter required to supply it weighs about 7 pounds. This same control system has been redesigned to operate directly from the missile 400-cps supply and weighs no more than 20 pounds. Because of the versatility of the Hybrid III magnetic amplifiers they may be used as summing amplifiers, demodulators, or operational amplifiers and will accept either d-c signals or a-c signals of power frequency. ■

wind tunnel progress

▪ The transonic tunnel of the Air Force's new facilities at the Arnold Engineering Development Center at Tullahoma, Tennessee was placed in operation in 1956, and aerodynamic tests have been started. The supersonic tunnel, the other portion of the Propulsion Wind Tunnel, is almost completed and is scheduled for operation in late 1959.

KVA Rate Limiter—The total drive for the Propulsion Wind Tunnel consists of four motors—totaling 216 000 hp—which will power both the transonic and supersonic tunnels. The drive can be split in the middle, providing power for each tunnel separately, or all four motors combined into a single drive to power either tunnel.

Because of the size of the motors involved, some special requirements were placed on the regulating system. For example, during starting and acceleration, a kva rate limiter will prevent the drive from taking excessive power from the electric system. By keeping the maximum power drawn to 30 000 kva per minute, the tunnel can be accelerated in the minimum time and yet stay within the capacity of the electric system. The electronic regulating system also controls the rate of machine acceleration and limits current to protect the machines. When on the line, a kilowatt regulator insures that the synchronous motors (two 83 000-hp machines) are loaded first; the remainder of the load is placed on the 25 000-hp induction motors.

During shutdown the regulating system acts in reverse to insure that the whole load is not dropped in one piece, again because of the severe shock to the electric system that would otherwise result.

Hypersonic Wind Tunnel—Continual advancements in wind-tunnel design are necessary to aid in the design of hypersonic aircraft now in the drawing-board stage. A wind tunnel being built for the Jet Propulsion Laboratory of the California Institute of Technology will accelerate a stream of air and direct it through a test section at a speed that can be varied from Mach 5 to 9, or approximately 3500 to 6500 miles per hour. This high air speed is accomplished by isentropic expansion of air through an aerodynamically shaped nozzle. To build a wind tunnel for air velocities in this hypersonic range, it is necessary to cool the walls to protect the wall material. This involves protection of the walls by a special metal cladding process.

Using complete wall cooling, this tunnel, when completed, will have the highest speed airflow in a large tunnel available to industry for aerodynamic testing. ▪

water tunnel

▪ The testing of aerodynamic models in wind tunnels is a well-known and established practice; hydrodynamic models will soon have the same opportunity in a new 36-inch, variable-pressure water tunnel under construction at the Navy's David W. Taylor Model Basin. The size and speed range covered by the new hydrodynamic test facility will permit testing models and propellers for which previously there have been no adequate facilities.

The water-tunnel pump drive consists of a large low-speed, synchronous 3500-hp motor, which drives the pump through an electromagnetic coupling. Pump speed (water flow) is controlled by varying the slip of the coupling.

Propellers are powered under test by two dynamometer-type drive motors rated 1750 hp at 3578 rpm, but capable of operating from 0 to 4600 rpm in either direction. This variable speed is obtained from two 1875-kva variable-frequency generators, each supplying power to one propeller drive dynamometer. The two variable-frequency generators are a part of a 3-unit motor-generator set, each being connected to the 2500/1250-hp double-ended motor through a magnetic coupling. By controlling the slip of these couplings, generator frequencies of 4 to 78 cycles are obtained.

Each drive motor of the dynamometer set is direct-connected to a speed increaser, which steps 4600 rpm to 10 000 rpm. If speeds below 4600 rpm are wanted, an interchangeable through-shaft unit can be substituted for the speed increaser.

The speed increaser or through-shaft unit is direct-connected by means of a three-foot hollow floating shaft to a thrust-bearing unit, and further to the propeller drive shaft. Any differences of alignment between the water tunnel and the propeller dynamometer drive sets are compensated for in this floating shaft unit at speeds up to 10 000 rpm in either direction. ▪

LAMPS AND LIGHTING

bright future for light of the future

▪ Activity on Rayescent electroluminescent panels has been greatly intensified during 1957; in one year's time, it has progressed from a basic research stage to pilot production and initial order stage. The first commercial application now planned will be in the slide-rule dial on the station selector of a new Westinghouse radio set. The electroluminescent panel will operate on 120 volts, 60 cycles.

Better than one hundred lamps have been shipped for experimental purposes. Typical applications being studied are decorative wall panels, radio dials, appliance indicators, name plates, and subdivided lamps for elevators and automotive dashboard panel lighting.

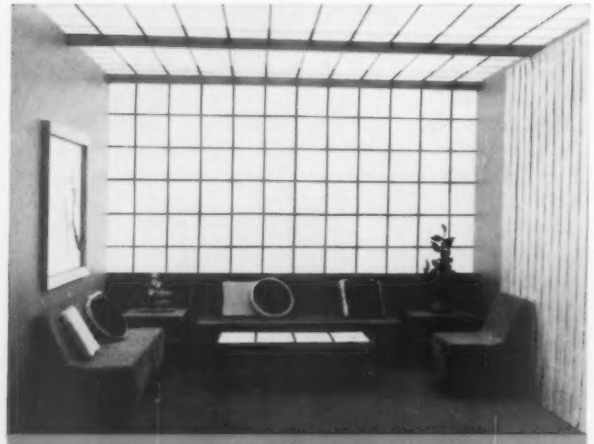
Meanwhile, research on electroluminescent phosphors is continuing at a rapid pace. For one, brightness at lower frequencies has been improved. Green color intensities that formerly took 300 volts at 3000 cycles can now be produced at 300 volts and 60 cycles. The efficiency of electroluminescent phosphors, particularly in the green range, have been improved from nine to twelve lumens per watt. Scientists are working to determine why electroluminescent phosphors decrease in brightness with burning at a more rapid rate than the fluorescent phosphors. They are also working on a transparent electroluminescent film, which would give light when voltage is applied and otherwise remain transparent. This would make possible windows that would light rooms with daylight during the day, and electroluminescence at night.

On other fronts, the use of low-melting point glass for embedding electroluminescent phosphors is being investigated. This would produce nonfragile cells. Likewise, embedding phosphors in plastic would permit flexible cells. A pilot-line production facility is being installed so that engineers can improve the techniques of production, such as increased uniformity and improved cell construction. The future of electroluminescence looks bright indeed. ■

mercury vapor goes commercial

■ Previously used primarily for street and industrial lighting, where light efficiency is more important than color, mercury-vapor lighting is now equipped to step into stores, offices, schools, auditoriums, or practically any other type of commercial application. By applying a combination of additive and subtractive color correction, the excessive yellow-green color has been subdued in favor of the more flattering warm colors. The electric-discharge in the inner quartz arc tube produces natural blue-green-white visible light and ultraviolet radiation. The outer bulb is coated on the inside surface with a phosphor which converts the ultraviolet to rich red. On the outside, a permanent purple-pink luster (colloidal metallic coating) has been added to filter out the excess of yellow-green rays. This reduces light output somewhat but results in a deluxe color quality, flattering to the human complexion and well balanced in all colors of the spectrum. The new Deluxe White lamps are made in ratings ranging from 400 to 1000 watts.

A new bulb shape has been designed for mercury lamps where semi-indirect lighting is desirable. The lower half of the bulb is phosphor coated and the upper half lightly frosted, resulting in an upward component of approximately 70 percent of the light. These are now made in the 400-watt size, either in the standard Golden White for high output or the new Deluxe White where double color correction is desired.



The many possible uses of electroluminescent lighting are illustrated in this model room. The windows in the rear with a transparent phosphor would allow daylight during the day and yet permit the viewer to look out. At night, transparent phosphors would help illuminate the room. The ceiling covered with electroluminescent panels would produce an even, uniform light. Decoratively, electroluminescence is used in the wall hanging and coffee-table top.

Since the distribution of the light is 70 percent up and 30 percent down, the fixture itself need provide little additional light control. Also the entire reflecting surface of the lamp is protected from dust and dirt, which keeps efficiency high. The lamp was especially designed for concentric ring fixtures such as are commonly used in schools, offices, and public buildings. The average bulb brightness is approximately 7400 foot lamberts for Deluxe White and 9000 foot lamberts for standard Golden White. ■

super-hi fluorescent lamps

■ A new fluorescent lamp (Super-Hi) produces 2½ times as much light as the previous standard rapid-start lamp. The development was made possible by use of a mixture of rare gases that permit extremely high-energy loading of the electrode arc stream, and the phosphor. The proper vapor pressure necessary to high operating efficiency, and which would normally be exceeded as the wattage of the lamp is increased, is obtained by the use of cooling chambers located at each lamp end. Developed primarily for medium- and high-bay industrial and outdoor lighting, the new lamps offer economy in those and similar fields of use. Now made in 48, 72, and 96-inch sizes, the lamps are rated at 6000, 9300, and 13 000 initial lumens respectively.

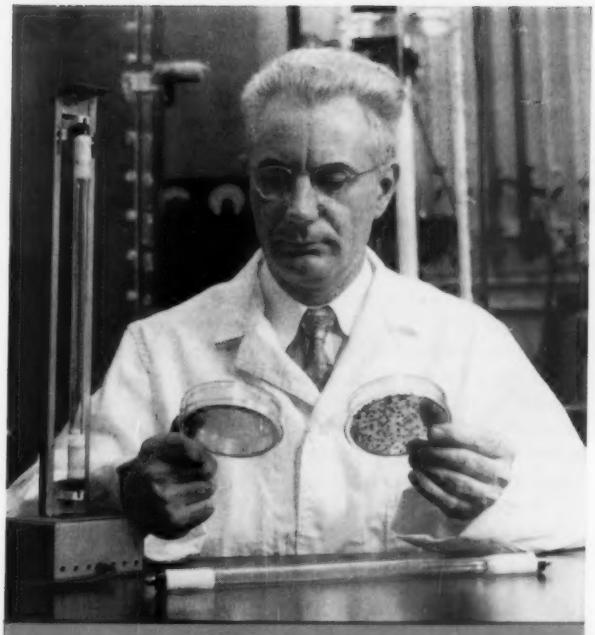
Built-In Reflectors—Directional light distribution has been obtained in fluorescent lamps by applying a reflective surface extending the length of a lamp on the inside of the tube. This surface redirects about 60 percent extra light out the other side. The reflector-fluorescent lamp is of principal interest where reflectors are difficult or impractical to use, such as in coves and showcases.

Built-In Filters—Fluorescent "black light" lamps are now made with deep blue tubing, which provides an integral filter, eliminating the need for filter plates on the fixture or the use of blue tubing slipped over the lamp, greatly simplifying the application of "black light."

Bacteria Barrier—A new ultraviolet lamp sets up a barrier of death to bacteria, virus, and molds. The new Sterilamp (G10T5½H) produces radiation 100 to 1000 times more effective in killing micro-organisms than an equal amount of ultraviolet radiation from the sun. The new lamp is especially designed for use in homes and is intended for insertion in heating and air-conditioning ducts. Tests have shown this high-output Sterilamp tube to be 2½ times as potent as previous lamps of this size. Eighty percent of air-borne virus and bacteria can be destroyed by inserting a single ultraviolet lamp in a heating or air-conditioning duct. ■

new applications for short-arc mercury

■ The arc stream of a mercury lamp used for general lighting service ranges from a few inches up to several feet in length. By compressing this arc down to a fraction of an inch, the source becomes about ten times as bright as a tungsten filament, and approaches the intrinsic brightness of a high-intensity carbon arc. These short-arc lamps were first developed for military purposes, but the high-brightness point source has made them ideal in the field of optics, where their use is ever expanding. Two new interesting applications were made this year: In one case, short-arc lamps were used in the projectors in the New York Stock Exchange to project stock quotations on the walls of the Exchange. The 1000-watt lamps produce nearly three times as much light as the lamps used previously. In a second application, a 2500-watt short-arc lamp is being used in a new airport beacon marker at the Washington, D. C. Airport. It will guide pilots during take-



Laboratory plates containing bacteria samples demonstrate the effectiveness of the new ultraviolet lamp. The plate on the left was exposed to contaminated air which had passed through a duct containing an ultraviolet lamp; the lamp was turned off for the plate at right.

off on one of the runways up the Potomac River, thereby reducing noise over populated areas.

A new 250-watt short-arc mercury lamp has been designed, which provides a much smaller arc (only a few millimeters) than its bigger brothers. Its principal use will be in optical instruments where a point source is important, but the larger size of the bigger lamps is not needed. Unlike the larger versions, which are single quartz bulb lamps, the 250-watt lamp is a double-bulb arrangement. The arc is contained in an inner quartz bulb, which is mounted inside a standard projector bulb with a medium prefocus base. ■

more light for flying

■ Since commercial flying has become so popular, airlines cannot afford delays caused by restricted visibility conditions. A new condenser-discharge approach light is part of a high-intensity lighting system enabling pilots to make approaches and landings during inclement weather and at night. The unit produces a short, very bright flash of light; when units are arranged in a line leading to the airport runway, the appearance resembles a string of tracer bullets fired from beneath the airplane toward the runway. The light flashes are produced by alternately charging a capacitor to relatively high voltage, then discharging the capacitor into a tightly coiled quartz tube containing xenon gas under pressure. The current surge heats the gas to a brilliant incandescence. A timing system triggers the flashes twice a second, flashing the unit at the outer end of the lights first then each successive unit in the line 1/60 of a second later. Thus a line of 20 units, spaced 100 feet apart, produces a streak of light that travels 2000 feet in $\frac{1}{3}$ of a second, repeating twice each second. The new systems are installed at Boston, Los Angeles, and Washington, D.C.

Flush Runway Lighting—At many runway intersections, a gap of 300 to 800 feet often exists in the lines of lights outlining the runway, since lamps could not withstand the high impact and static loads at these intersections. A new concept in runway lighting, the flush runway light, can be installed directly in the runway paving in the path of maneuvering aircraft. This flush light permits continuation of rows of high-intensity runway lights through runway intersections; permits narrow gauge runway lighting, where lights are installed parallel and close to the runway centerline; and provides lights that may be installed in a line across a paved runway to designate a true threshold, or a high-speed taxi turnoff. Nearly level with the runway pavement, the fixture is so tough that it withstands anything likely to be on a runway. ■

new fluorescent luminaire for street lighting

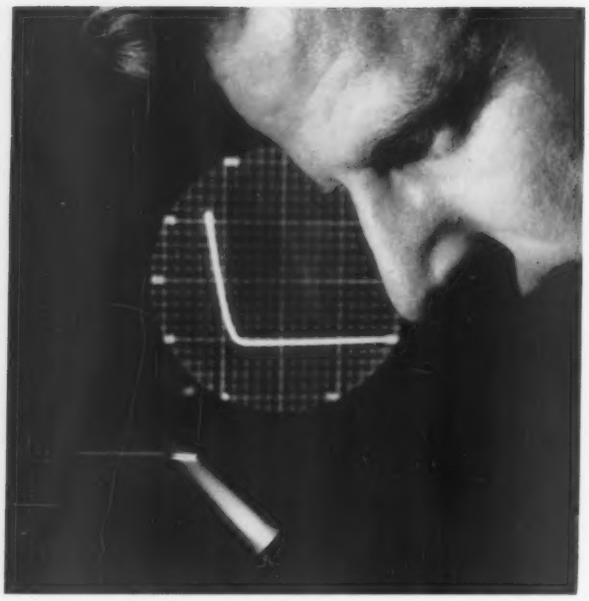
■ Since the advent of fluorescent street lighting in this country several years ago, fluorescent street lamps have been mounted perpendicular to the curbline; lamp reflectors provided vertical light control only, while units enclosed by a clear plastic globe provided no light control. This optical system did not adequately direct light onto the street area. The coefficient of utilization, which is a measurement of the percent of light that strikes the pavement surface to the percent of light emitted by the lamp was approximately one-third that of the highly developed optical systems used with incandescent and the mercury-vapor lamps. A major step forward in fluorescent luminaires for street lighting has improved this coefficient of utilization 1½ to 2 times that of present fluorescent fixtures. This is accomplished by mounting lamps parallel to the curb, and employing a prismatic plastic refractor to provide additional light control. The complete optical system of the lamps, a specular Alzak reflector and the plastic refractor, has the higher utilization of the bare lamp output with a correspondingly reduced cost on a per-lumen-of-light basis. The new luminaire is offered for use with two six-foot fluorescent lamps operating at either 1000 or 1500 milliamperes and will produce a maximum of approximately 20 000 lumens of light. The new design is a joint development of Westinghouse and the Holophane Company, who manufacture the plastic refractors. ■

SEMICONDUCTORS AND ELECTRONICS

rectifier operates "red hot"

■ For the past 25 years, silicon carbide has been used for non-linear resistance elements in lightning arresters. Using the electrical characteristics of the material, scientists have adapted it for use in semiconductor single-crystal devices. As a result, a grown-junction large-area rectifier has been developed that can operate "red hot" with a 200 degrees C rise above an ambient temperature of 500 degrees C. This is in a temperature range where previously no materials have operated and is two to three times higher than any temperature at which rectifiers have previously operated.

Of course, the electrical-grade silicon carbide used for lightning arrester applications was not pure enough for semiconductor use. Materials engineers studied the methods for making silicon carbide and have now arrived at a material with less than one part per million impurity. The hexagonal-shaped crystals one-quarter inch in diameter are prepared in a specially designed furnace operating above 2400 degrees C using an atmosphere of super-pure argon or helium. These grown junctions will act as rectifiers with peak inverse voltages of several hundred volts and up to 10 amperes. ■



This silicon carbide rectifier is operating "red hot." Characteristic curve is displayed on oscilloscope screen.

world's purest silicon

▪ The semiconductor material to watch in developments of solid-state devices, such as transistors and rectifiers, is silicon. Present transistors, for example, are predominantly made from germanium, but scientists have known that silicon transistors could find broader applications because of silicon's inherent higher temperature limits and excellent electrical characteristics.

Such high-grade devices were made possible last year with the development of an ultrapure silicon, with impurities less than one part in six billion. Devices with two to four times the voltage and power handling capacities of those now in use can be made with ultrapure silicon.

As an illustration, silicon transistors now carry ratings of 60 volts, 2 amperes with a gain of 10 to 15 db. Experimental transistors of the new silicon have provisional ratings of 300 volts and 20 amperes at the same gain. Rectifier voltage ratings can be raised from the present top of 600 volts to 1000 volts or more. Single crystals of the ultrapure silicon have a resistivity of 400 to 1000 ohms with a lifetime of 400 to 800 microseconds, which is about five times better than present available materials.

The process for manufacturing ultrapure silicon was developed by Siemens & Halske A. G. and Siemens-Schuckertwerke A. G. in Germany, in cooperation with Westinghouse scientists. Companies in this country will be licensed to manufacture the material. ▪

high-power silicon-rectifier assemblies

▪ Coupled with the recent development of ultrapure silicon for extra-high-power transistors and rectifiers have been additional applications of present silicon diodes.

New high-power rectifier assemblies employing standard silicon cells can replace motor-generator sets, mercury-arc rectifiers, vacuum tubes, and selenium rectifiers for many applications. The assemblies combine small space requirements and rugged construction with a nearly unlimited range of ratings. The largest unit designed to date has an output rating of 0.2 amperes at 250 volts d-c. These assemblies will be used in welding equipment, battery chargers, aircraft power supplies, arc furnaces, d-c motor armature supplies, cathodic protection, and electrochemical power supplies.

As many as 600 silicon diodes are mounted under oil in a precipitation transformer tank for rectifying high a-c voltages. Requiring smaller space than the equivalent selenium unit, this rectifying bridge can be mounted directly in a transformer tank without materially increasing tank size. The assembly efficiently handles high voltages and low currents; a typical d-c rating is 35 to 60 kv at $\frac{1}{10}$ to $\frac{1}{2}$ amperes. ▪

dynistors

▪ With remarkable regularity, new semiconductor devices have been developed in recent years to perform functions hardly dreamed of a decade ago. The most recent newcomer in this field is the Dynistor diode. With the switching characteristics of a transistor and the power-handling capabilities of a rectifier, it offers some outstanding potential applications in power control.

The forward and reverse voltage-current characteristic of the device is similar to a conventional diode, except that when the applied voltage in the reverse direction exceeds the rated peak value, the device breaks down to a very low resistance state. Thus the device is effectively an open or closed switch as a function of the applied voltage.

Germanium units rated at 350 volts have been operated with continuous currents up to 10 amperes. Under pulsed conditions, Dynistor units rated at 2 amperes have passed 500 amperes for 5 microseconds. These values are only representative of one particular device and work is in progress on units with continuous ratings up to 250 amperes.

One of the most interesting properties of this device is the switching time in going from a blocking or high-resistance condition to a conducting or low-resistance condition. This breakdown or turn-on time is less than 0.1 microsecond. Alternating-current switching circuits using Dynistors have been made to switch 1 kva operated from Cypak inputs. Thus Dynistors can be used to replace relays so that complete truly static power switching circuits can be constructed with no moving parts. ▪

infrared detector "sees" cooler objects

▪ The number of devices from semiconductor materials appears to be endless. One of the latest is an infrared detector using the photoelectromagnetic (PEM) effect in a semiconductor material, indium antimonide. With this new principle of operation, the cell is superior to typical photoconducting-type devices in that it eliminates cooling that was necessary for previous detectors of this type, and has both a lower noise figure and shorter response time. The PEM detector measures infrared radiation by the action of a magnetic field on photo currents in the material, with an increased wave length response over conventional detectors. Since infrared detectors "see" hot objects, this new device can detect things that are at much cooler temperatures. ▪

new electronic tubes

▪ *Television*—The size of the tv picture tube normally dictates cabinet dimensions for home television receivers. Stretching the cathode-ray tube beam-deflection angle from 90 to 110 degrees has permitted receivers to take another "slenderizing" step. Two 110-degree types, 17CDP4 and 21CEP4, are widely used in this year's models.

A new electron gun has been designed for the 14-inch

"portable" cathode-ray tubes (14ACP4 and 14NP4A), which permits low first anode voltage (E_{G2}). While the advantages of the new design are somewhat technical, the result is greater picture contrast for the same video drive—or, more economical set design without loss of picture quality. This development is being extended to 110-degree types.

Receiving tube designers are busy making changes necessary to keep in step with the improved line of cathode ray tubes. For example, the 12DT5 vertical amplifier tube, a miniature pentode, has been especially designed to drive the new 110-degree picture tube. The advantage of this tube is that it can use 250 volts on both plate and screen.

A companion 12EN6 pentode, also a vertical amplifier for television receivers, is most suitable for use in sets that operate with about 125 volts on the anode and screen.

And Hi-Fi Too—With the rejuvenation of interest in high-fidelity sets, the need for a quieter pre-amplifier tube became apparent. The 12DF7 twin triode was developed for pre-amplifier service, where the peak audio signal is small. Hum and the microphonic tendency must be unusually low so that extraneous or background noise will not be introduced into the system. Special care has been taken in the heater treatment, and in rigidly supporting tube elements.

Midget-Sized Camera Tube—A new ½-inch vidicon tube (WL-7089) has been developed for compact television camera service. It is a tetrode version, with a grid (G_3) for electrostatic focus. When a new tube is installed, the grid voltage can be adjusted to compensate for variations in individual tube or circuit characteristics.

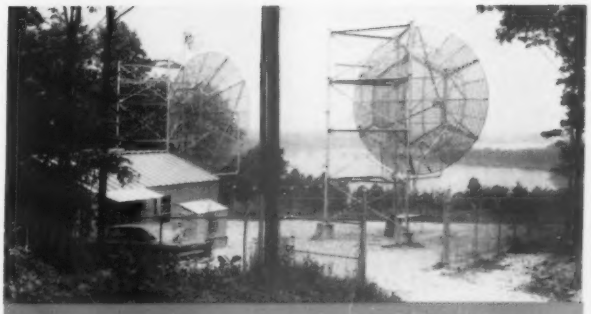
This tube makes possible a much more compact miniaturized television camera. The overall tube dimensions—3 inches long and ½ inch in diameter—called for radical design changes, not merely a scaling down from existing tubes. The stem leads have been designed to fit the standard seven-pin miniature receiving tube socket. This new vidicon is expected to open up many additional fields of application for tv cameras, both in industry and entertainment.

Altimeter Magnetron—The WL-6177 frequency modulated altimeter magnetron has been introduced. It is used to provide a radio-frequency beam that is aimed downward from a plane. The return of the signal to the plane gives a continuous measure of its height above the terrain. It is particularly useful in providing very accurate observations at low altitudes. To do this, the beam is frequency modulated by a vibrating tuner incorporated within the envelope of the tube. The typical output is about one watt and the center operating frequency is approximately 4300 megacycles.

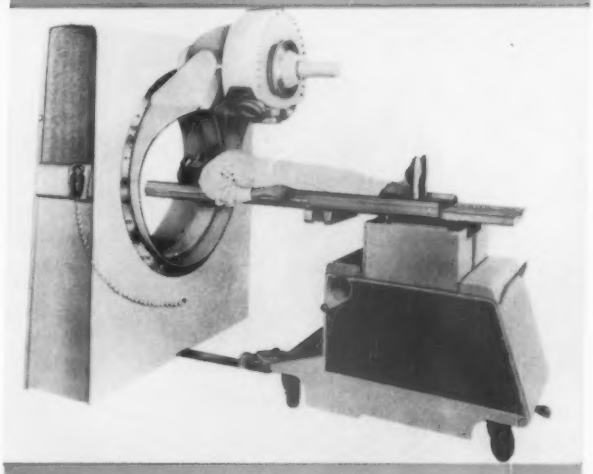
Clipper Diode—A new clipper diode (WL-6898) possesses several novel features, such as ruggedness and small physical size. It has an external copper anode with attached aluminum radiator and is very compact. It can be used to absorb any undesired residual energy from the pulse applied to a magnetron in a radar system, thus preventing false responses. It may also be used as a conventional rectifier for converting a-c to d-c at either high or low voltage.

Neutron-Detector Tubes—A boron-lined uncompensated ionization chamber, WL-6937, has been designed for the detection of thermal neutrons. This is a comparatively economical tube for atomic-reactor control at high power levels. A design modification permits operation at temperatures up to 300 degrees F.

A high-sensitivity proportional counter tube, WL-6938, has been developed for control during the reactor startup. This tube permits the reactor to be monitored most carefully during this critical period. ■



The advent of beyond-horizon communications systems has provided a valuable adjunct to line-of-sight radio relay systems, particularly in the far North, and other inaccessible areas. Although present scatter systems employ frequency modulation, system studies have shown that single sideband can provide many important advantages for scatter transmission including higher reliability, greater voice channel capability on a single carrier, better quality voice channels, and radio spectrum economy. Westinghouse has developed a 72 voice-channel, 2000-mc SSB scatter system which is presently being evaluated on a link between Baltimore, Maryland and Verona, New York, a distance of 268 miles. Shown is the Baltimore terminal of this system.



This Cobalt 60 teletherapy machine administers high-energy radiation for treatment of cancer and other malignancies. Although teletherapy is an old concept even with radioactive material, the use of Cobalt 60 for the purpose is new. Cobalt 60 units can replace high-voltage equipment up to 3 mev.

The rotating "source" head permits primary radiation to be focused on a spot on the axis of rotation as small as one or two centimeters in diameter. Stationary beam techniques can also be used. A particular feature of the machine for operating convenience is the "Dial-A-Cone" turret, which permits quick selection of any one of seven therapy cones contained on the turret (for defining radiation beam). The rotating ring (hubless wheel) permits the patient to be positioned into or through the ring. Patient contact protection is accomplished electronically; if the patient or table is touched by a moving part, the machine shuts down. This device is fail-safe since the machine is inoperable unless the device is in order. A speed calculator automatically regulates the speed of the rotating machine according to the time and arc selected at the control.

4

RESEARCH AND ENGINEERING

Viewed from below, a flask containing a few ounces of a material called a clathrate gives off innumerable bubbles of a gas that was trapped inside the clathrate and has been released by solution.

caged gases

■ A gas you can hold in your hand? This scientific oddity is not science fiction, but an everyday reality to chemists who have perfected a method for trapping gases inside tiny, invisible crystal "cages." The process, called *clathrating*, is being developed by the Westinghouse Research Laboratories.

The term clathrate is derived from a Greek word meaning lattice, as in a cage. This is in effect what a clathrate is. Two chemicals are combined in such a way that one is physically caged within the crystal structure of the other.

In a crystal, the atoms or molecules are grouped into regular patterns having tiny spaces between them. In the research experiments, scientists allow a crystal to take shape in the presence of a suitable second substance, thereby trapping molecules of the latter substance inside the lattice.

Two conditions must be met if this trapping, or clathrating, is to be successful: first, the spaces within the crystal must be large enough to contain the trapped molecule; and second, the cages must be tight enough to prevent the molecule from escaping. Hence the clathrated material is physically captured in the crystal but not chemically combined with it. The molecule can move freely within its cage but cannot escape simply because it is too large to slip between the clathrate structure.

While the cage must consist of a crystalline material, the trapped substance can be a solid, liquid, or gas at room temperature. Some clathrates imprison a gas at an effective pressure as great as 1300 pounds per square inch. A clathrate is usually in the form of a white solid resembling ordinary sugar. By holding a lighted match under the solid, it is possible to melt it and observe the trapped gas molecules escape as bubbles under considerable pressure.

Although now little more than a laboratory curiosity, clathrating may someday be of considerable practical importance. Already scientists are exploring some of the future applications for the process. Of more immediate scientific interest, however, is the usefulness of clathrating in scientific research. The process isolates single gas molecules, which, for the first time, may make them available for individual study. Such study is extremely difficult under the conditions in which a gas is ordinarily found. Even under the best laboratory produced vacuums, there are about half a million molecules per cubic inch of gas.

Inside their separate cages in a clathrate, individual gas molecules sometimes produce startling behaviors. Oxygen molecules, for example, are ordinarily very active and combine chemically with a wide variety of substances. But in a clathrate, the oxygen molecules remain trapped and chemically inactive until they are released by heating the clathrate, dissolving it, or otherwise setting the molecules free.

The possibility of perfecting clathrating on a large scale leads to interesting speculation. For example, eventually it

might be feasible to have a monofuel for rockets. Since a rocket must carry its own supply of oxygen as well as its own fuel, if the oxygen-producing material could be trapped inside the fuel, separate tanks for fuel and oxidizing agent could be eliminated, thereby saving space and weight, and very likely simplifying rocket design. ■

microwaves and superconductivity

■ Scientists are using a combination of extremes—the highest frequency microwaves ever generated plus the lowest temperatures in the world—to help unravel one of the greatest riddles of modern physics: the "why" of superconductivity—that strange behavior of certain metals, in which electric currents apparently flow forever at extremely low temperatures.

Since electrons are known to be "carriers" of electricity, those in a superconductor must be in a very special state—one in which they can move about with no friction whatsoever. Physicists have speculated that they may be condensed out of the state in which they normally move through the metal. Unfortunately, this theory cannot be tested by direct observation of the electrons. The microwave experiments are the latest of several methods of attack on this problem which have been underway at the Westinghouse Research Laboratories for the last five years.

The super-frequency waves are used to bombard a superconducting metal such as aluminum or tin that is held at a temperature less than one degree above absolute zero. The waves are absorbed by the metal, which soaks up enough energy to lift its electrons from the superconducting to the normal conducting state. Measurements are made of the energy required for the different temperatures of the metal.

In a typical experiment, the microwave power absorbed by the superconductor is only about one-millionth of a watt. This tiny amount of power raises the temperature of the superconducting metal about one-thousandth of one degree. Yet, so sensitive are the thermometers used in the experiment, they can detect temperature changes a hundred times smaller, or only ten-millionths of a degree.

These microwave experiments, together with other experiments carried out at the laboratories, have shown that there is, indeed, a condensed electron state in superconductors. The results have already greatly increased scientists' understanding of the mechanism of superconductivity. They are presently extending their studies to even more detailed investigations. ■

test modulator for pulse transformers

■ The many faceted specialty transformer business requires a range of facilities to match. Recently, for example, the world's most powerful and versatile pulse testing modulator for testing high-power pulse transformers was put into operation.

High-power pulse transformers, used in radar transmitter circuits in conjunction with klystron and magnetron tubes, are sometimes required to deliver pulse peaks up to 50 megawatts with accurate pulse durations or widths in the microsecond range. The modulator is the heart of a test facility that evaluates the transformer by simulating the input and load conditions to determine if the transformer can meet response requirements. It also tests the ability of transformer insulation to withstand high-peak voltages and rough-duty ratios of average-to-peak power.

The modulator can simulate loads ranging from 1 to 50 megawatts peak, with pulse voltages up to 38.7 kv. It has a built-in protective circuit that removes high voltage immediately after one pulse wave of fault current.

A unique water-load rheostat is used to load transformer secondaries during load tests. Smaller than a conventional load resistor and having less capacitance to ground, its resistance depends on the salt concentration of the water.

The modulator, together with the other components of the test facility—the power supply, load and test booth, and a desk-type control console—can also be used for testing other radar transmitting components. ■

Microwaves help solve the riddle of superconductivity.

These little steel bb's—35 tons of them—are being installed as the shielding for a new hot cell. The cell has half-inch-thick steel walls spaced 15 inches apart. Between these walls are the 35 tons of bb's—equal to 10 inches of solid steel in their ability to "contain" atomic radiations. Use of the bb's makes the hot cell portable, since the shot can be drained through special openings near the base of the walls. The new hot cell will be used for examining the effect of a nuclear environment on reactor materials, for studying the usefulness of atomic radiations in industrial processes, for finding ways to utilize the radioactive by-products from nuclear power plants, and for related atomic and nuclear research.

Facilities for testing high-power pulse transformers.

Left—A high-temperature strain gauge was made possible by this mirror—platinum brazed on Refractaloy.

Center—In this flight-simulator laboratory, airborne electronic components can be put into "service." The analog computer generates the solution to systems of simultaneous differential and algebraic equations, linear or non-linear. The simulator gives essentially a 1-to-1 relationship to physical parameters, and affords a means of exploring adjustments to produce desired system performance. Among the systems analyzed thus far have been the Aero 13 interceptor fire-control system, the Aero 21-B bomber tail-defense system, the W3A autopilot system, and the Bomarc missile guidance system.

Right—Its own vastly enlarged structure silhouettes the microscopic study of Cubex steel.

high-temperature testing

■ The design of materials and electronic components for high-temperature applications is not the end of the high-temperature story. These materials and devices must be compared to those now performing at ordinary temperatures, and for this reason engineers must adapt standard tests to give high-temperature data.

One such test measures the standard magnetic losses of materials used by design engineers. To do this, laminations of the material to be tested are stacked in a device called an Epstein frame. Formerly the frame was constructed of standard materials—cardboard and wood, ordinary cloth and resin insulation, and copper wire. To test materials for high-temperature use, however, these parts had to be replaced since they would not stand up under the conditions of a high ambient temperature test. Now the Epstein frame is made of ceramic materials with silver-plated brass contacts, glass cloth impregnated with an inorganic polyphosphate material for insulation, and silver wire. A special high-temperature cement holds the entire device together.

In a similar setup, inductive electronic components, such as transformers, are tested at temperatures up to 600 degrees C. These tests are necessary because the performance of inductive components changes at elevated temperatures.

This testing is all part of high-temperature development work by materials engineers. If components can be developed to operate at elevated temperatures, the need for auxiliary cooling devices is lessened, and generally devices can be made smaller in size. ■

high temperature optical-strain gauge

■ The testing of materials will never become routine as long as new materials are developed and older ones are improved. This is particularly true in the case of alloys designed for 1200 and 1250 degrees F operating temperatures. Where can delicate instruments be found to measure physical properties of alloys at such temperatures? In some instances, the building of an instrument to do the job involves almost as much work as the development of the high-temperature alloy itself.

One important metal property required is the variation in modulus of elasticity at elevated temperatures. Also vital is the degree of surface strains incurred by heat cycling. To obtain this information, a standard optical gauge used for measuring strains at room temperature was adapted for high-temperature service.

The small instrument, roughly $1\frac{1}{2}$ inches long by $\frac{3}{4}$ inch wide by $\frac{5}{8}$ inch high, consists of a metal framework to hold two tiny mirrors, one stationary and the other movable. The mirrors are mounted on blocks of Refractaloy alloy, which have one knife edge that contacts the sample. In operation, the gauge is clamped to the metal surface, a beam of light is aimed at one mirror, reflected to the other mirror, and then back to the light source where a scale indicates the angle of the return beam of light. When the sample is strained at test temperatures, the movable knife edge rotates slightly, changing the mirror angle and in turn the light beam return angle. Since there is no mechanical linkage between the strain gauge and the measuring device, an extremely high degree of accuracy is possible. With proper calibration, changes as small as 20 millionths of an inch at room temperature and 80 millionths of an inch at 1250 degrees F can be detected.

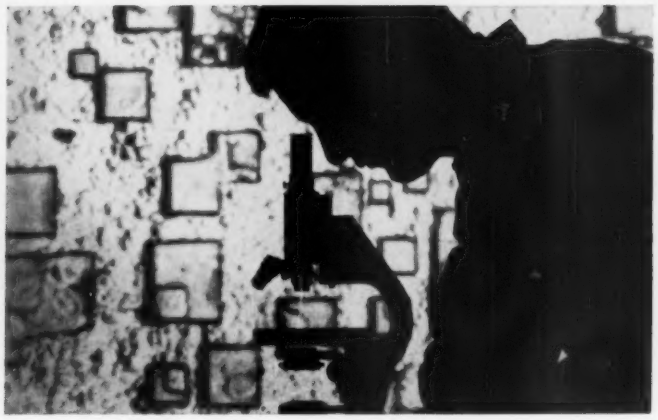
The chief difficulty from a materials standpoint in adapting the room-temperature gauge to a high-temperature gauge was the mirror surfaces. A successful combination consisted of silver brazing a $\frac{1}{8}$ by $\frac{5}{16}$ inch strip of 30-mil-thick platinum to the Refractaloy knife edge blocks. Even at 1250 degrees F, the platinum stays bright and reflective and the 80 millionths of an inch accuracy is now almost as easy to obtain as it was at room temperature. ■

corrosion resistant balancing alloy for steam turbines

■ The bothersome thumping of an automobile tire can sometimes be eliminated by balancing the wheel, i.e., adding weights at certain points around the rim. But when it comes to balancing high-speed steam-turbine rotors, unbalance is considerably more than a mere annoyance.

Contrary to the tire-balancing method of adding weights at the proper point, holes are actually drilled and material removed from a rotor at specific points. The reason: no heavy material was available with sufficient corrosion resistance to withstand the operating conditions of a turbine rotor. Metallurgists have long sought such a high-density, corrosion-resistant material.

A new material, with a specific gravity of 16.8, satisfies the requirements. Utilizing the inherent high density of tungsten, and combining it with a lower melting point nickel-base alloy containing from 10 to 30 percent chromium, the material has the corrosion resistance needed in a balancing alloy. Now holes can be drilled and tapped in a rotor at the proper points and stud sections of the new alloy screwed in.



The poor corrosion resistance of pure tungsten has been overcome in an unusual way in the new alloy. Powders of the tungsten and the nickel-chromium alloy are mixed and fired at high temperatures; the latter alloy melts and coats each of the tungsten particles, thereby binding the tungsten into a solid mass and effectively preventing the tungsten from coming into contact with corrosive high-temperature steam. Pressed parts of the new alloy can be made to almost any shape, but as far as balancing is concerned they are confined to studs ½ to 1¼ inches in diameter and from 4 to 6 inches long. Plugs in the shaft are placed either parallel to the rotor shaft or radially. ■

cooled turbine blades test themselves

■ Cooled turbine blades represent a blending of heat-exchanger principles and aspects of a high-speed rotating component, with the complications of elevated-temperature operation. The design feature by which the core conducts heat away from the blades is used in a novel inspection technique by aviation gas-turbine engineers.

In blade manufacture, examination of the brazed bond between internal fins and the external skin has always been a problem since it is invisible, improperly located for x-ray, and too small for ultrasonic testing.

The heat-exchanging features of the blades actually perform the test. The entire assembly, which consists of a massive finned core—shaped like a turbine-blade airfoil—and a thin metal wrapper bonded to the tips of the fins to form the outer skin of the foil, is chilled in an acetone-dry ice bath. As soon as the part is removed from the bath, it starts to warm. The skin warms first, except at sound fin-skin joints where the massive core acts as a heat sink. A stream of moist air passed over the outer skin forms frost lines wherever the brazed joint is acceptable, since the core draws heat away from the skin surface at these points. Where frost lines are thin, the joint is porous. If no frost forms, there is no solid connection between the skin and the cold finned core. This technique is being used in the development of the cooled turbine design. ■

double barreled facility speeds turbine development

■ New ideas and equipment were combined to provide improved metallurgical laboratory facilities for aviation gas-turbine engineers. The facilities are divided into two labs—one to study materials, and the other to study the interrelationship between a material and the process during fabrication.

The Materials Testing Lab will provide accurate and reliable metallurgical data on the behavior of high-temperature alloys rapidly and efficiently. To do this, innovations in design and administration had to be employed. Special scheduling, work flow systems, time and motion studies, and new testing techniques have increased productivity while maintaining high standards.

The Process Development Lab is equipped with small pieces of equipment, which can be combined into an integral unit capable of performing the functions involved in complex manufacturing operations. Modular construction of the equipment increases the versatility of the lab and speeds the development of new processes.

Activities at the two labs include studies of low-frequency vibration on the grain structure of precision castings, the welding of reactive metals, the heat treatment of super alloys, high-temperature stress concentration and fatigue tests, and other more involved investigations. ■

four-way magnetic steel

■ Cubex steel—a new "four-way" magnetic steel—will permit magnetism to turn around corners in magnetic circuits, such as cores of transformers and motors. Although not yet graduated from the laboratory, the new steel has seen rapid development since its first technical disclosure more than a year ago. When Cubex is developed to the commercial stage, it will make possible smaller, lighter, and more efficient electrical equipment.

The new magnetic material is a steel technically known as "doubly-oriented silicon-iron," or "cube-oriented silicon-iron." The unique metallurgical processes involved in preparing the new silicon-iron were originated by scientists of Vacuumschmelze, a subsidiary of Siemens & Halske in Germany. Westinghouse research scientists have extended this work and provided basic information necessary to develop the material to its present state of perfection. In preparing the new material, a new mechanism for crystal growth in metals has been discovered. As a result, the new silicon-iron has a unique crystal arrangement, contrary to that normally encountered in the metal, and difficult to bring into being. The crystal arrangement in the new cube-oriented magnetic steel might be compared to the arrangement of a tray of ice cubes. Each cube rests flat on one side and squarely faces the ends and sides of the tray. Since the edges represent easy directions of magnetization, good magnetic paths exist along both the width and length of the sheet. The crystals in ordinary singly-oriented silicon-iron are arranged so that only the lengthwise magnetic path exists.

The process responsible for producing cube-oriented silicon-iron has been shown to be operative in sheets thick enough for use in large transformers and motors. Thin strip, which is much easier to prepare, has been produced on a pilot-plant scale. Such strip, about five thousandths of an inch thick, is of the dimensions used in radar transformers, relay cores, and similar electronic and electrical equipment. Hence, special uses requiring only thin sheet will probably be the first commercial applications of the material. ■

ultrapure niobium

■ Niobium, a comparatively rare element, offers excellent promise as a structural metal for high-temperature application above 1800 degrees F. Niobium (formerly called columbium) is a member of the family of the higher melting point "transition" metals such as chromium, molybdenum, and tungsten. The urgent need for better high-temperature structural ma-

terials has prompted a fundamental study of the element.

Niobium has unique high-temperature properties. Unlike most metals, it does not lose its room-temperature strength drastically with increasing temperature. At 2000 degrees F—just about the melting point of copper—it has roughly the same strength as molybdenum and is several times stronger than the best available nickel-base and cobalt-base alloys at this temperature. Niobium also has valuable structural characteristics. It is only slightly heavier than iron, and is not brittle at room temperatures as are other high-temperature metals such as chromium and molybdenum.

Because it is so active chemically near its melting point of 4380 degrees F, molten niobium must be handled in a vacuum or in an atmosphere of some inert gas such as helium or argon. For the same reason, niobium of extreme purity cannot be prepared by melting it in any sort of crucible or similar container. Two methods—cage-zone melting and levitation melting—both invented by Westinghouse research scientists, are being used to prepare high-purity niobium.

Cage-Zone Melting—A rectangular bar of impure niobium is placed vertically on a movable platform, which moves up and down inside a coil of heavy copper tubing. The coil and platform are enclosed in a sealed vessel with a vacuum only four billionths the pressure of atmosphere. A strong high-frequency electric current in the coil melts the bar from the inside out. The four corners of the bar do not melt, but form a "cage" within which the molten niobium is trapped. The niobium bar thus serves as its own crucible within which the white-hot metal is refined. As the bar rises through the coil, a molten zone of niobium travels down the bar from top to bottom, melting the bar progressively throughout its entire length. Successive passes of the rectangular bar through the coil result in niobium of increasing purity as more and more impurities are removed.

Levitation Melting—In levitation melting, compressed metal powder is placed inside a copper coil that carries high-frequency current. The r-f field generated floats the metal charge inside the coil, and at the same time converts the metal into a white-hot molten mass in a matter of seconds. Temperatures of 4500 to 5000 degrees F can be achieved in half a minute or less. The process is carried out inside a sealed vessel containing an inert gas, thereby protecting the pure metal from contamination from the air.

Although niobium has not yet graduated from the laboratory, scientists feel that this latest wonder metal may soon contribute to an outstanding high-temperature, high-strength structural metal alloy. Niobium has moved a step closer toward its expected use in rockets, missiles, jet engines, and nuclear reactors of the future. ■

tungsten research

■ Tungstic acid is the starting material used in the manufacture of tungsten filaments, the basic components of electric lamps. Reduction of this compound with hydrogen yields tungsten metal powder, which is converted into solid metal by powder-metallurgy techniques. Small amounts of silica, potassium chloride, and alumina are added to the tungstic acid prior to reduction to produce desirable structural and mechanical properties in the final wire. The mechanisms by which these desirable properties are attained is a subject of considerable research, but still unknown. Hence, to evaluate these specific effects of impurities in tungsten, the initial tungstic acid is needed with a minimal amount of impurities. The commercial product has a purity of approximately 99.9 percent. Research scientists are preparing an experimental processing facility that will improve this figure to 99.95 percent, and eventually possibly as high as 99.99 percent.

Another approach to determine the role of the impurity additions to tungsten is being followed. Recent experiments have shown that certain impurity additions strongly retard recrystallization behavior and increase its high-temperature creep strength in wire form. To further investigate this, single tungsten crystals are being prepared, which will be used for further studies of recovery, resistivity, and particularly crystal plasticity. ■

strange crystal growth may explain steel failure

■ Tiny crystals of matter, in a form never before seen by man, may hold the answer to one of the least-understood problems in modern metallurgy—*stress-corrosion cracking* in metal structures that are chemically corroded while under an internal or applied stress. The newly discovered crystals (back cover) grow as delicate plates from the surface of stainless steel that is exposed to corroding atmospheres containing traces of negatively charged chlorine atoms—more properly referred to as chloride ions. Research scientists believe that this unique crystal growth has an important bearing on the whole general problem of stress corrosion, since it has suggested a mechanism on the atomic scale to explain such corrosion. The growth of platelets on the steel surface could lead to a chemical cutting of the metal. Minute crevices might grow downward into the metal surface as the platelets thrust themselves above it. This could lead to stress concentration at the base of the crevices and eventually metal failure.

In a typical experiment, a small piece of stainless steel wire, nine thousandths of an inch in diameter and subject only to the residual stresses it normally possesses, was exposed to a carefully controlled atmosphere of oxygen and water vapor at a red-hot temperature of 1100 degrees F. With very pure oxygen and water vapor, the surface of a typical sample of stainless steel erupts with billions of oxide "whiskers." These whiskers (back cover) are about two millionths of an inch in thickness and grow to a height 300 to 400 times their diameter. Their density is about six billion per square inch of metal surface.

But completely unexpected changes occur in this crystal growth simply by prestressing the stainless steel and adding the slightest trace—less than five parts per million—of chloride ions to the atmosphere. Instead of long thin filaments, rows of thin, upright, parallel plates growing along a definite crystallographic direction are formed. Under the electron microscope, these crystals are easily penetrated with a 60 000-volt beam of electrons, placing their thickness at a half millionth of an inch or less. Analysis shows them to have the characteristic structure of an oxide of chromium, Cr_2O_3. Chromium is normally present in stainless steels, and each tiny plate appears to be a single crystal of its oxide.

For some time scientists have known that the chloride ion is a major factor in producing stress-corrosion cracking of stainless steel. It now appears that the chloride ions can stimulate the growth of these unique, plate-like crystals in a strongly stressed metal, which growth might result in cracking and ultimate failure of the steel.

The experiment described is typical of a new approach to the whole problem of corrosion, an approach that seeks a better understanding of the fundamental mechanisms involved. Such an understanding, research scientists believe, will come from carefully controlled experimentation on the atomic scale, not from observations that depend upon massive effects under relatively uncontrolled conditions. ■

ENGINEERING HIGHLIGHTS IN CONSUMER PRODUCTS

On previous pages, we have discussed engineering progress mostly for industrial and military application. Not to be overlooked are many solid engineering advances in consumer products. Herewith, a sampling for 1957.

BEHIND THE SCREEN DEVELOPMENTS FOR TV SETS. A look at the complicated "insides" of a television set shows that much engineering thinking and design time have gone into its construction.

Automatic Fine Tuning—In the modern television receiver, two criteria are necessary for good *fine tuning:* (1) the sound-picture carrier ratio at the video detector must be such that the sound is approximately 30 decibels below the picture signal, and (2) the picture carrier should be located at about 6 decibels below peak intermediate-frequency response. The first requirement insures good audio quality and noise suppression without sound interference in the picture; the second provides good picture sharpness. A new automatic fine tuning (AFT) circuit maintains these two essential criteria.

In the conventional television set, an automatic gain control circuit maintains the picture carrier level at a constant value. The new AFT circuitry also measures sound carrier level, and acts to maintain the picture-sound carrier ratio at the proper value by controlling the local oscillator frequency.

In the conventional TV receiver IF passband, the picture carrier will always be located 4.5 megacycles from the sound carrier. The IF passband for the new AFT receiver is similar to the conventional passband except that it has a much steeper slope at the sound-carrier frequency. With this steep sound slope, high AFT loop gain is achieved which acts to reduce drift of the local oscillator. This loop gain is high enough so that variations in sound-picture carrier ratio due to transmission propagation conditions or antennas vagaries produce negligible frequency errors, and hence excellent picture quality.

In fringe areas, where the signal is relatively weak and consequently the signal-to-noise ratio is poor, the AFT receiver may be set by the customer to automatically move the IF picture frequency to a position of high response. This can be done manually on conventional IF passbands, but AFT gives the advantage of automatically selecting this condition for any individual channel, after being preset for "fringe" performance.

Wireless Remote TV Control—Television viewers can now use carrier current—the method of sending radio-frequency signals over power lines—to switch channels or lower sound of their sets without moving from their comfortable armchairs. The control signals, generated by a small transmitter at the viewer's fingertips, are carried via house electrical wiring to the receiver, there activating relays that control channel switching or sound muting. The system is particularly suited for receivers employing automatic fine tuning as described above.

Carrier current has several advantages as a signal transmitting medium. The power required to operate the transmitter is easily supplied by plugging into any convenience outlet—and a path for the carrier-current signal is simultaneously provided. This direct path for the signal results in relatively low attenuation, so that a low-power transmitter and relatively low-gain receiver will provide positive and fool-proof remote control.

The viewer switches channels or mutes sound by moving a two-position switch on the transmitter to either the *select* or *soft* position. The switch will latch in the *soft* position to hold the sound at a low level.

Transmitter output is in the order of 12 milliwatts for continuous-wave operation, and considerably less for the modulated wave. Field testing has shown this power level sufficient for positive operation, yet low enough that units installed in adjacent houses supplied from the same pole transformer will not interfere with each other when operating on different carrier frequencies.

COLD INJECTION. New refrigerators have an entirely new refrigerating system—a forced-air circulating system. A blower-type fan changes air in a 10 cubic foot box twice a minute. Where air circulation is dependent on convection currents, as in previous refrigerators, the change is in the order of once every five to ten minutes. The new rapid change of air means that cold air lost from frequent door openings is recovered much faster; that warm foods placed in the refrigerator are chilled much more quickly; and that a more constant temperature is held throughout the food-storage compartment.

The cycle works something like this: when the compressor and air-circulating fan are both running, the air stream carries the heat extracted from the food out of the food-storage compartment over a cold plate located between the rear inner and outer walls. As soon as the temperature of the cold plate reaches zero degrees F, the compressor is turned off but the fan is left running. When the warm air stream coming from the food-storage compartment raises the temperature of the cold plate to 36 degrees F, the compressor is turned on again, and the cooling cycle repeated.

The secret to the uniform temperature in the food-storage compartment is the constant turn-on temperature of 36 degrees F for the plate. The inside temperature is controlled to within one degree F because of the air change twice a minute. This means that for the new refrigeration system—called "cold-injection refrigerating"—the control is responsive to the food-storage conditions and not to room temperature.

Also for the new line of refrigerators, engineers have designed a new condenser—a wire-and-tube design in place of the customary sheet-and-tube arrangement. The new design serves as a more efficient heat exchanger and allows better air circulation. The capacity of the wire-and-tube condenser is determined by tube length. This permits greater flexibility in condenser manufacture so that the condenser can be matched to a specific refrigerator capacity.

HEAT FROM COLD. The first of the new "space saving" series has been added to the Westinghouse heat pump family. Designed specifically for the southern market, this dual-package unit requires as little house room as a conventional furnace and yet provides complete summer and winter air conditioning. Versatility is the keynote of the indoor section which can operate equally well in the up-flow, down-flow or horizontal position, permitting installation in closets, utility rooms or crawl spaces. The outdoor section is located conveniently outside the house.

MOWER MOTOR CIRCUIT BRAKES BLADE. A new concept of safety was introduced with a circuitry innovation on the new induction-motor-powered Scotts Lawn Mower. The 19-inch cutting blade is brought to a standstill within three seconds in free air (average of one second in grass) after the motor power is turned off; this, combined with the regular Duo-Guard protective circuit that takes the motor off the line if it is stalled, provides maximum safety to the operator.

To start the motor, both a fast starting switch and a special "dead man" or handle braking switch must be depressed until the motor is up to speed. The starting switch is then released and the motor continues to run until the "dead man" switch is released. If the motor is overloaded or blade rpm is reduced below good cutting speed, it is removed from the line by the centrifugal switch in the Duo-Guard circuit; restarting is accomplished by depressing the starting switch. When the "dead man" switch is released, a regenerative-dynamic braking circuit is actuated and the motor is quickly brought to a standstill.

Thus, the mower will run while the operator is grasping the "dead man" switch in his position of safety well away from the whirling blade and can be started only by use of two members of the body. This eliminates the possibility of injury during mower cleaning, or by unintended restarting due to a bad plug-in connection.

These electron microscope photographs give scientists a new look into the cause of stress-corrosion cracking of stainless steel. When corroded at high temperatures with pure mixtures of water vapor and oxygen, millions of tiny oxide "whiskers" (left) result. But when the metal is pre-stressed, and a trace of chloride ions added to the corroding atmosphere, delicate sheets of crystals—never before observed by man—erupt from the metal surface (right).

Scientists believe that growth of these tiny crystals, about half a millionth of an inch thick and 120 millionths high, may cut tiny canyons into the metal's surface and eventually lead to metal failure.